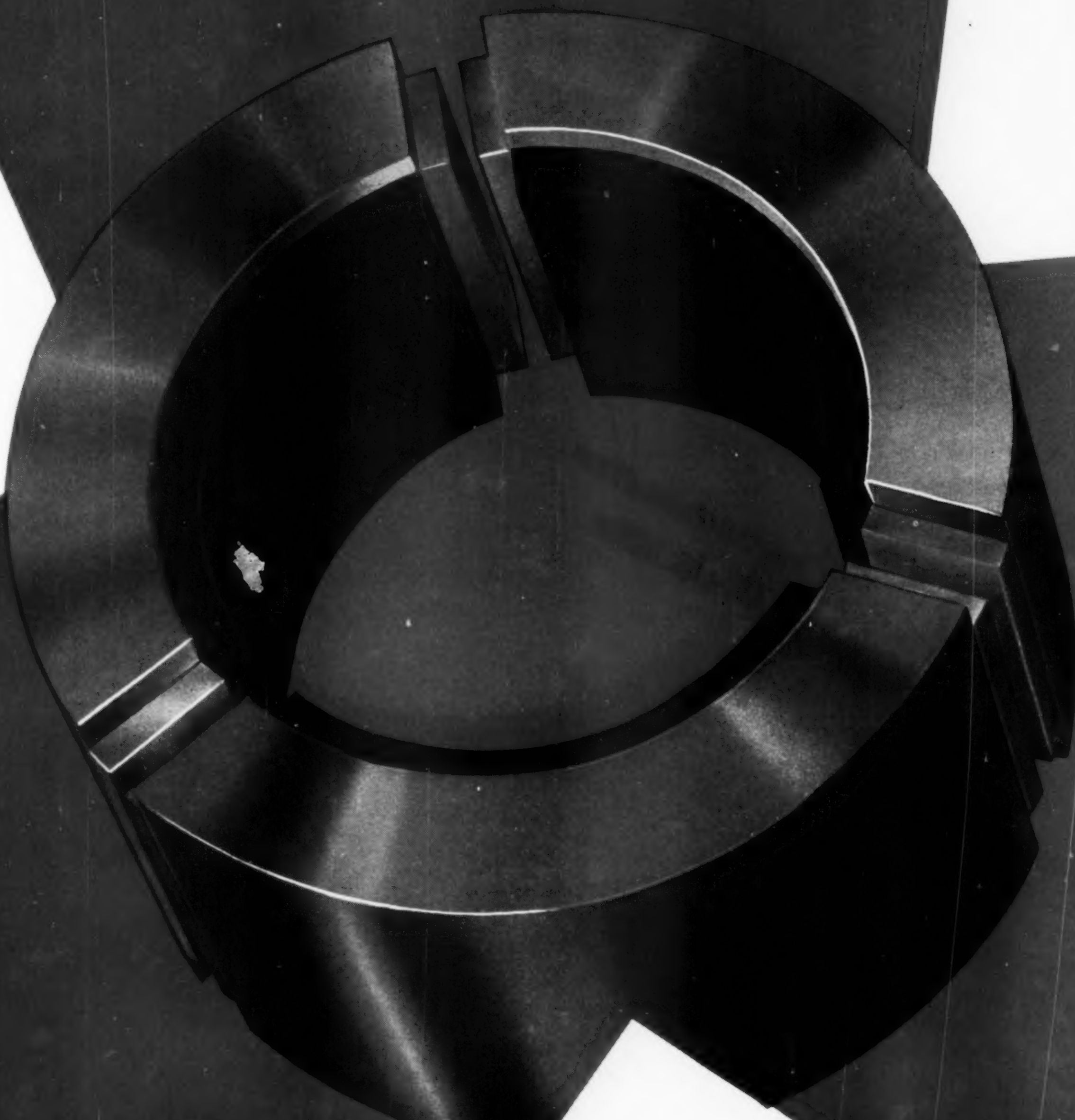
621

DECEMBER 27, 1956
EVERY OTHER THURSDAY

MACHINE DESIGN

A PENTON PUBLICATION



Pivoted-Shoe Bearings

Contents, Page 3

FLEXIBLE SHAFT IDEAS for ENGINEERS

For driving or controlling inaccessible parts flexible shafts do a better, more economical job

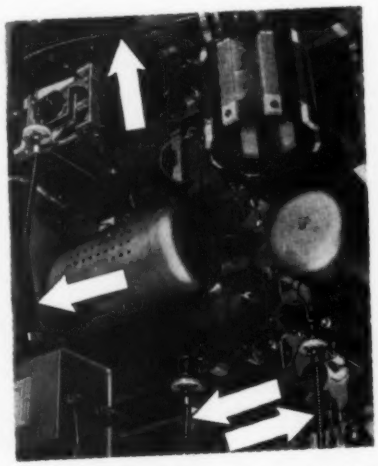
Fewer design problems, better placement of elements, easier assembly are a few of the advantages

250,000 miles at 90 mph and still going strong

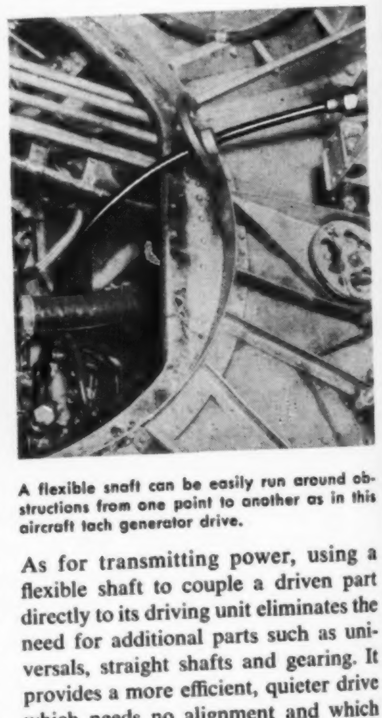
To prove our claims about the long life and dependability of S.S.White flexible shafts, we conducted accelerated life tests on a number of S.S.White speedometer shafts. After being run at 90 mph for 250,000 miles—the equivalent of being "driven" 10 times around the world—the shafts were still going strong.

Here is information every designer should have

Bulletin 5601 contains the latest information on flexible shafts. Included are full details on how to select and apply power drive flexible shafts as well as up-to-date tables showing flexible shaft sizes and characteristics.



In this electronic circuit, flexible shafts run between variable elements and control knobs give extra freedom in locating parts to best advantage.



A flexible shaft can be easily run around obstructions from one point to another as in this aircraft tach generator drive.

The Ready Adaptability of S.S.White flexible shafts in meeting varying design requirements makes them one of the most versatile elements available. And nowhere does this adaptability count for more than in providing an efficient, low-cost drive or control for parts that must be mounted in hard-to-get-at locations.

For remote control applications, this means additional design freedom in mounting controls in more advantageous operating positions. It also means more efficient placement of controlled parts to satisfy space, operating and service requirements.

As for transmitting power, using a flexible shaft to couple a driven part directly to its driving unit eliminates the need for additional parts such as universals, straight shafts and gearing. It provides a more efficient, quieter drive which needs no alignment and which can be installed faster, with fewer problems.

S.S.White flexible shafts are made in a large selection of sizes and characteristics to enable you to meet a wide range of application requirements.

Full engineering cooperation in selecting and applying flexible shafts to your products is always available.

F6-7

S.S.White FIRST NAME IN FLEXIBLE SHAFTS

S. S. WHITE INDUSTRIAL DIVISION, DEPT. 4, 10 EAST 40th ST., NEW YORK 16, N.Y.

Western Office: 1839 West Pico Blvd., Los Angeles 6, Calif.

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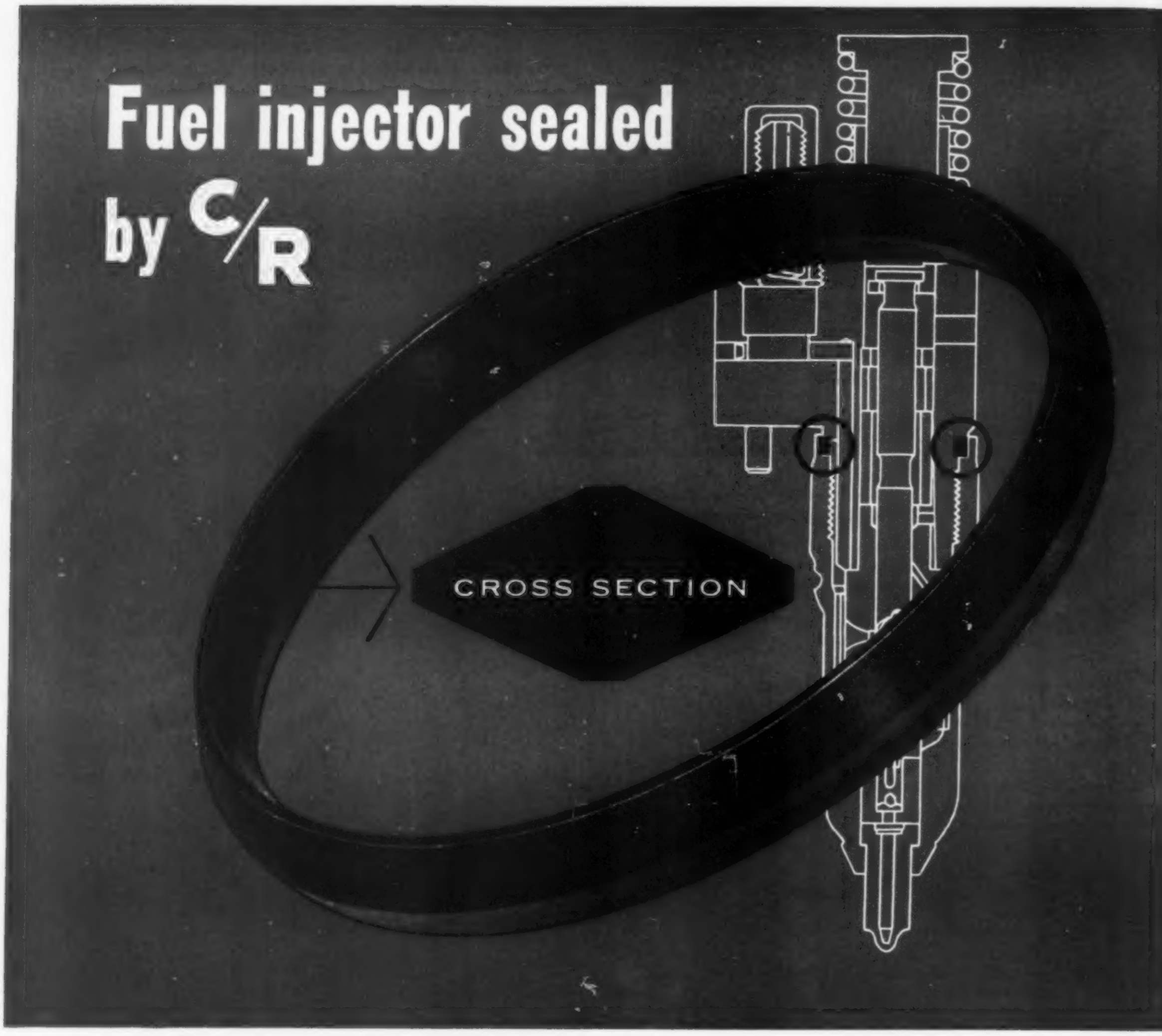

ELIMINATES INJECTION NOZZLE LEAKS

Crankcase dilution can be a big headache. But not for one of the leading Diesel manufacturers. They knew that the right injection nozzle seal would cure a major cause . . . and came to C/R Sirvene engineers for help. C/R manufactured this Sirvene (synthetic rubber) part to extremely critical dimensions and physical properties to match the equally precise dimensions of the assembly. Result: no more leakage. When you need a pliable mechanical part compounded to meet critical specifications of heat, pressure, abrasion resistance and molded to the most exacting tolerances, you need C/R Sirvene. C/R Sirvene engineers will gladly cooperate with you in all phases of your sealing problem . . . from design, compounding of the correct oil-resistant elastomers, through laboratory-like control of production quantities. Write for your copy of the new booklet, "Sirvene."

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THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

December 27, 1956
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Machine Design is sent at no cost to management, design and engineering personnel whose work involves design engineering of machines, appliances, electrical and mechanical equipment, in U. S. and Canadian companies employing 20 or more people. Copies are sent on the basis of one for each group of four or five readers. Consulting and industrial engineering firms, research institutions and U. S. government installations performing design engineering of products are also eligible.
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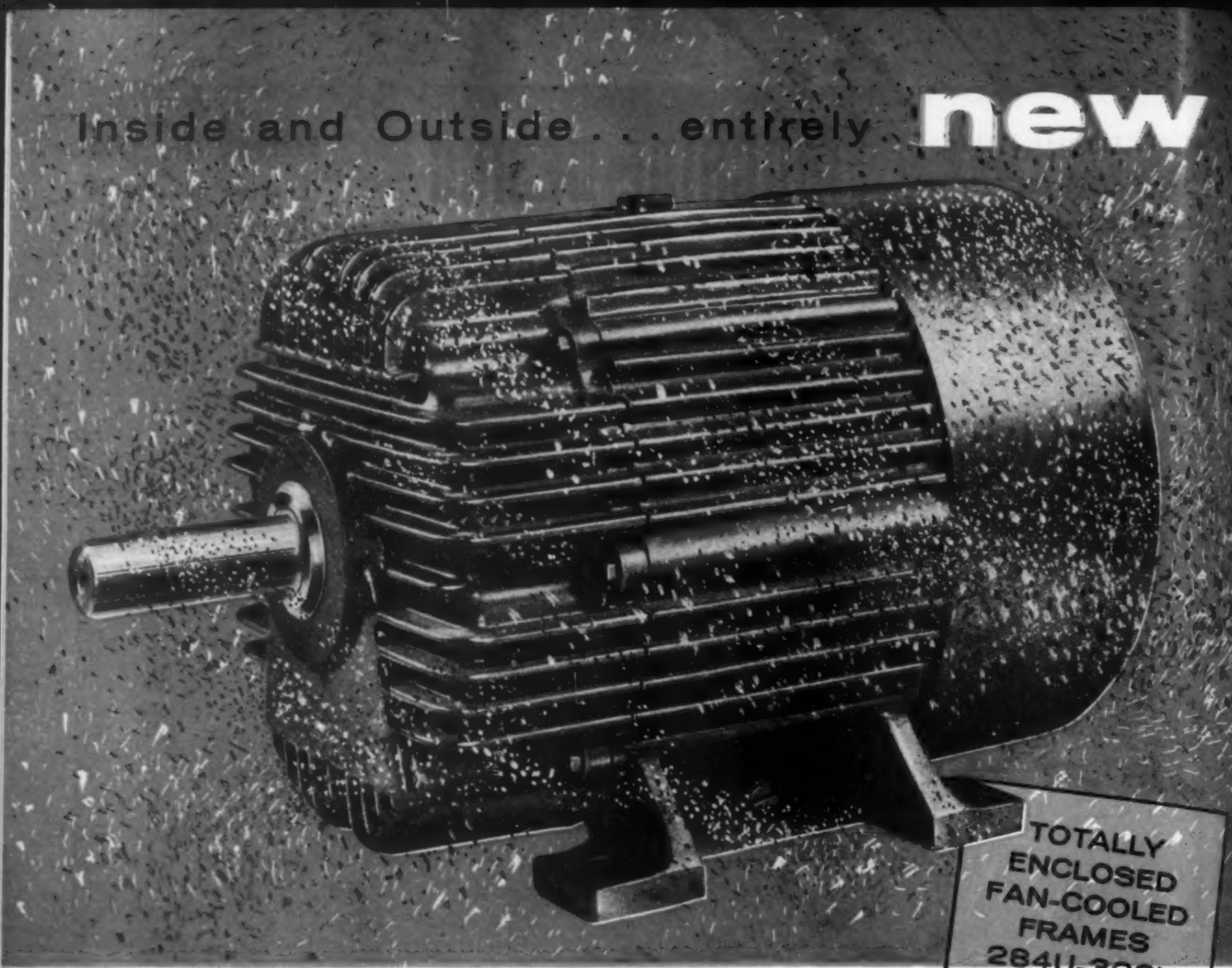


NEW Elliott C-W type N Motor PERMANENTLY SEALED Against Dust, Moisture, Corrosive Fumes

The rugged "Sealedpower" cast frame Elliott motor shown above is the modern version of the design pioneered in this country by Crocker-Wheeler. An external fan, made of sparkless material, and surrounded by a cowl, blows air along the frame for highest cooling efficiency. An internal fan provides continuous air circulation within the enclosure. All openings in the frame are tightly sealed, providing complete protection to windings and working parts.

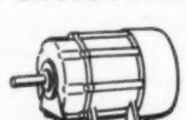
Once applied only in locations where extremely destructive atmospheric conditions prevail, totally-enclosed motors are today rapidly gaining acceptance for all types of applications. Users find that the total over-all cost—first cost plus maintenance—is less than that of open or semi-enclosed motors.

Ask your Elliott representative for details, or write for the new type N motor bulletin. Address Elliott Company, Crocker-Wheeler Division, Jeannette, Pennsylvania.

OTHER C-W TYPE N MOTOR ENCLOSURES


Totally-enclosed non-ventilated


Dripproof Protected


Totally-enclosed, fan-cooled Frames 256 U and smaller

ELLIOTT Company
CROCKER-WHEELER DIVISION

We will be glad to send a copy of this new booklet describing the complete line of Elliott C-W type N motors. Please write on company letterhead.

W6-6

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Engineering News Roundup

Council Seeks Action on Shortage of Engineer Aides

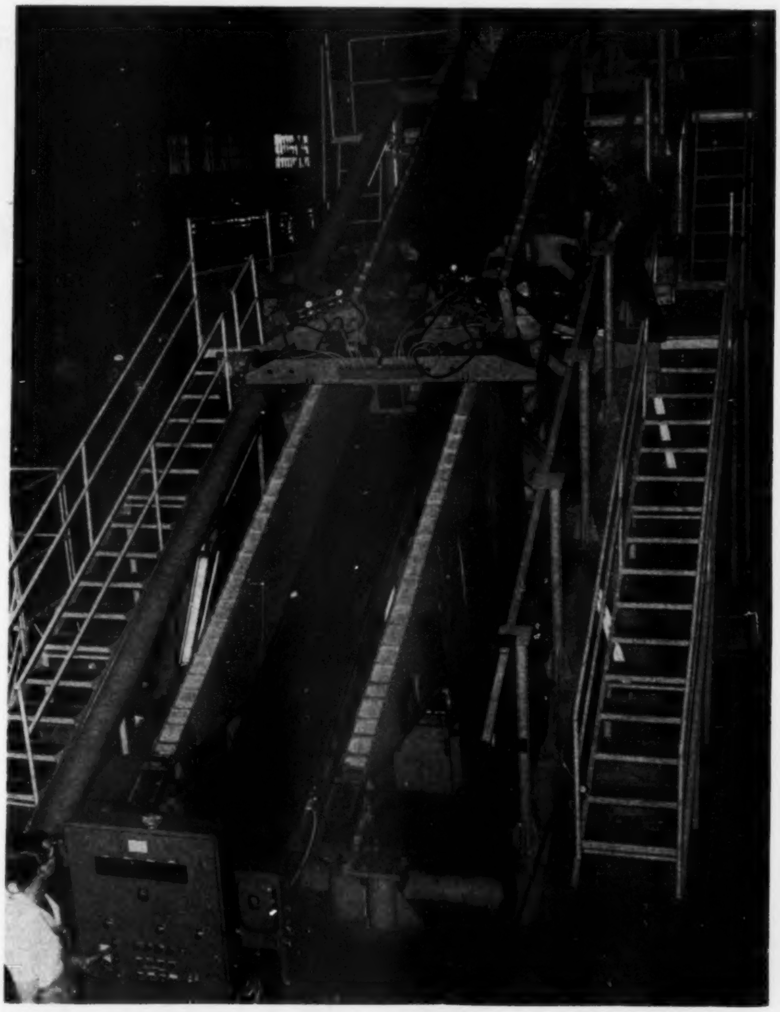
PAOLI, PA.—Engineering support personnel are just as scarce as engineers themselves, and concerted action must be taken immediately to remedy the situation. These were the observations of 280 representatives from industry, education and government who met recently at the Research Center of the Burroughs Corp. They comprised a Workshop of the Design and Drafting Council of the Delaware Valley. Their objectives were immediate plans and a long-range program for relieving current pressing shortages of draftsmen and engineering aides.

The Council finds that while the need for engineers has been widely publicized, little attention has been focused on the diminishing supply of "second echelon" personnel. This second echelon is composed of draftsmen and technicians urgently needed to fill support jobs currently done by engineers.

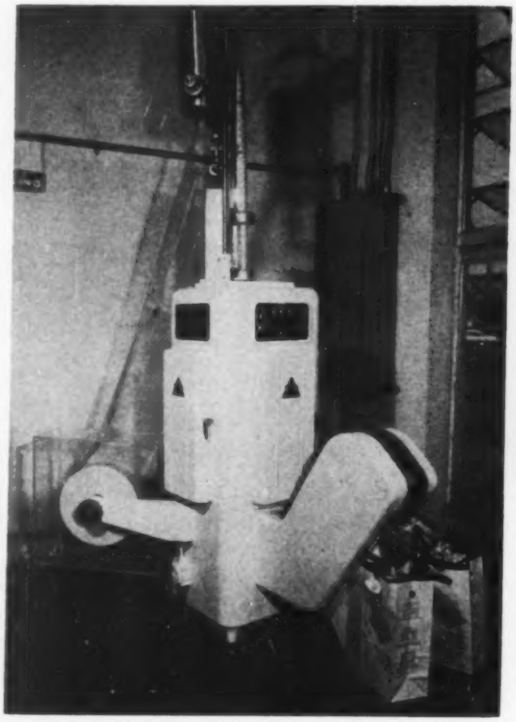
Thomas W. Hopper, executive vice-president of Day & Zimmerman Inc., told Council delegates that it has been estimated in Philadelphia "the cost of advertising for draftsmen and designers has amounted to almost $25,000 per week." Time has proven that this apparently is not the answer, or an effective approach to solution of the over-all problem.

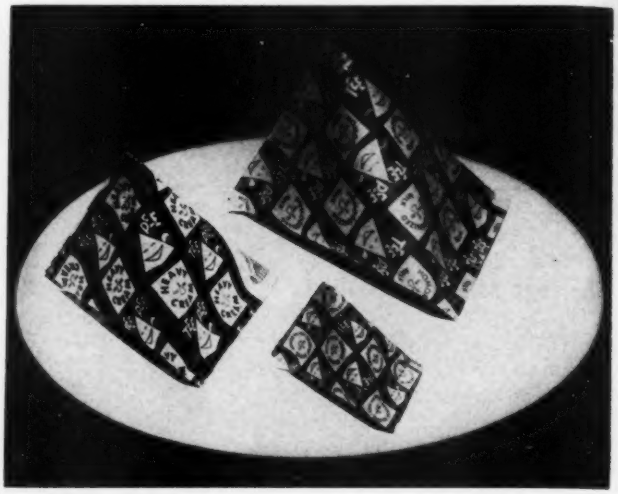
Panel discussions at the Workshop sought recommendations for immediate partial solutions and ultimate complete solutions to the support personnel shortage. Subjects under discussion in the panels included pre-industry training in schools, the place of training in the design and drafting fields, specialized training for upgrading, the means by which training programs can be sold to management, training for drafting supervisors, and specialized training for work peculiar to operations.

Delegates to the Workshop recognized that the development foundation for skilled workers must be in the junior, senior, vocational,



EQUAL TRIANGLES are assured with this new equipment developed by Convair to machine simultaneously, in pairs, the delta wings for F-102A jet interceptors. The combination tool and fixture is 169 in. wide, 361 in. long and 252 in. high. Here it performs the first of three operations—trimming the wing skins along the leading edge spar. The trim is 31 ft long; held straight and parallel to ±0.010-in. The trim is cut by four ½-in. diam end mills driven at 22,000 rpm by air turbines mounted on a bridge assembly. The bridge is driven up and down the bed by its own motor geared with a rack in the machine bed. Automatic switches limit bridge travel.

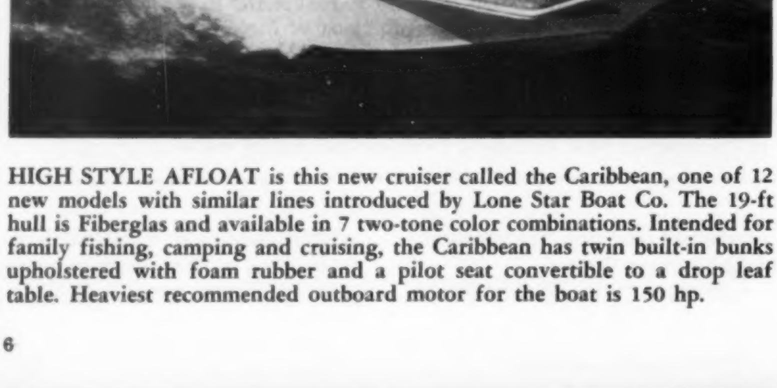




MILK IN PAPER PYRAMIDS, called Textra Paks, is the product of this Swedish machine recently introduced in the U.S. for the first time. A roll of paper lined with polyethylene is formed into a tube, pinched at the base, filled with liquid, then pinched again at right angles. Cutters separate individual units. The absence of air in filled containers helps the product keep longer. The packaging method permits economical marketing of dairy products in small units.

and technical high schools. It was recommended that courses of instruction be concentrated on basic drawing mechanics and techniques, a good command of basic mathematics, a general knowledge of materials, and particular emphasis on accuracy.

It was also suggested that overage personnel with years of experience in the fields of design and drafting be encouraged to reenter the drafting room, or utilize their specialized "board" experience in teaching these fields in the public schools.



HIGH STYLE AFLOAT is this new cruiser called the Caribbean, one of 12 new models with similar lines introduced by Lone Star Boat Co. The 19-ft hull is Fiberglas and available in 7 two-tone color combinations. Intended for family fishing, camping and cruising, the Caribbean has twin built-in bunks upholstered with foam rubber and a pilot seat convertible to a drop leaf table. Heaviest recommended outboard motor for the boat is 150 hp.

"Hot" Metals Now Examined With Remote Microscope

RICHLAND, WASH.—A remote controlled microscope developed by G-E for the Hanford plutonium plant is now being used to inspect materials giving off radiation that makes direct examination impossible.

The instrument enables the study of changes in microstructure that occur when metals are exposed to chain reaction bombardment. The pieces exposed to radiation become ray emitters themselves.

The sample is manipulated remotely inside a 38-ton steel cell by means of mechanical "hands" powered by electric motors. Elec-

Front Cover

Pivoted-shoe bearings have one unique feature: they are self-aligning, since the shoe can tilt to compensate for differences in load on the journal. Also, oil film whirl is eliminated, and abrasive "lubricants" can be handled easily. George Farnsworth's cover keynotes E. J. Cattabiani's article on pivoted-shoe bearings on Page 63.

trical etching equipment removes the top layer of metal which has been made into a "nontypical microstructure" by heat of the grinding.

Light beamed through a wall port is focused to a bright pin point on the polished sample. Reflected light from a circular dot of metal, sometimes as small as 0.005-in. diam, is collected by a compound lens and projected through another wall opening to an external eyepiece. There, it is transformed into a vastly enlarged image of the circular area.

The instrument can optically separate two elements of grain structure 0.001-in. apart. In effect, it places the observer's eye within 0.004-in. of a "hot" surface. The microscope protects the observer from radiation but it becomes damaged itself in the process. Its optics are said eventually to go "blind."

NEITHER SNOW nor mud nor underbrush stops the LeTourneau Transporter, which can climb steep embankments and travel over rough terrain. Designed to carry freight in areas not served by highways, it has a load capacity of 70,000 lb. The vehicle itself weighs 55,000 lb. Individual electric motors drive each wheel, and if one wheel loses traction its power is transferred to the others. The braking system utilizes regenerative action of the electric motors in the wheels. One control governs speed, power and braking. Electric steering is controlled by pushing a finger switch left or right.

Survey Finds Engineers Don't Want Engineer Unions

NEW YORK, N. Y.—Engineers have expressed strong opposition to engineering unions in a survey conducted recently by *Industrial Relations News*. The survey covered 633 engineers in companies of 1000 to 3000 employees located in northeastern and midwestern U.S.

Asked if they felt they were part of management, 50 per cent of young engineers 21 to 30 said "yes". The percentage increased with age.

At least 75 per cent of engineers of all ages said they would rather rely on their own initiative for their economic welfare rather than a union. Largest numbers who thought unions a definite hindrance were in the youngest age group.

The survey showed that differences between engineers in management and those in technical work exclusively were felt most keenly by young men and progressively less with age.

Half of the engineers thought that the existence of engineering unions had changed their status, and three-fourths of these thought the change was for the worse.

Asked, finally, if they believed in engineering unions in principle, 85

Topics

National Engineers' Week, to be observed February 17-23, 1957, has as its theme "Engineering—America's Great Resource." Purpose of the event is to bring before the public contributions which the engineering profession has made to modern living. Sponsors also hope that publicity given the observance of this week will encourage young people to enter the engineering profession.

• • •

Portable P-A system fits into a 14 by 18 by 6-in. case, weighs 18 lb. Components include a transistor amplifier, an 8-in. speaker and microphone. The system is rated by its manufacturer, Antrex Corp., as capable of handling an area of about 6000 sq ft without auxiliary speakers.

• • •

New engineering curriculum has been announced by Pratt Institute. A common two-year course of study will be followed by students in electrical, mechanical, industrial and chemical engineering. Emphasis will be on mathematics and science without specialization, except in the junior and senior years.

• • •

Speech compressor has been developed by an engineer at Temco Aircraft Corp. to squeeze the human voice into a narrow range for improved radio transmission. The transistorized unit compresses peak values of voice sounds to a 24-decibel limit which serves the needs of communication. Interference from background noises is reduced.

• • •

Cooling with gas is possible with equipment developed by the Le Roi Div. of Westinghouse Air Brake Co. Engines which burn natural gas power 75 to 500-ton air conditioning units. Advantages claimed for the use of gas are operating economy and automatic operation at variable speeds to meet cooling requirements.

• • •

First American supersonic bomber, the Convair B-58 Hustler, was reported "outstandingly successful" in its first test flight. The delta-winged B-58 is powered by four GE J-79 turbojet engines with afterburners. It is designed for altitudes above 50,000 ft.

Circle 408 on page 19→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TUBE
COPPER ★ BRASS
1801
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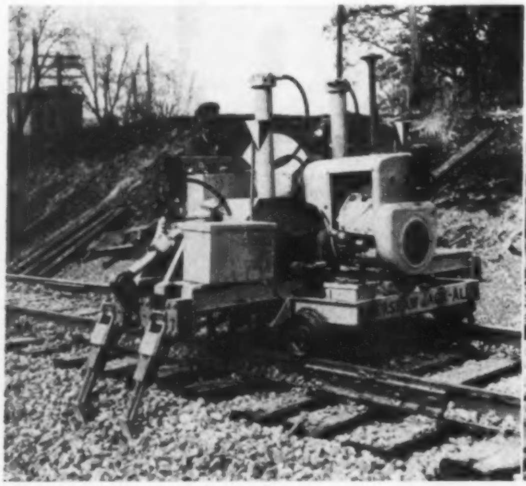
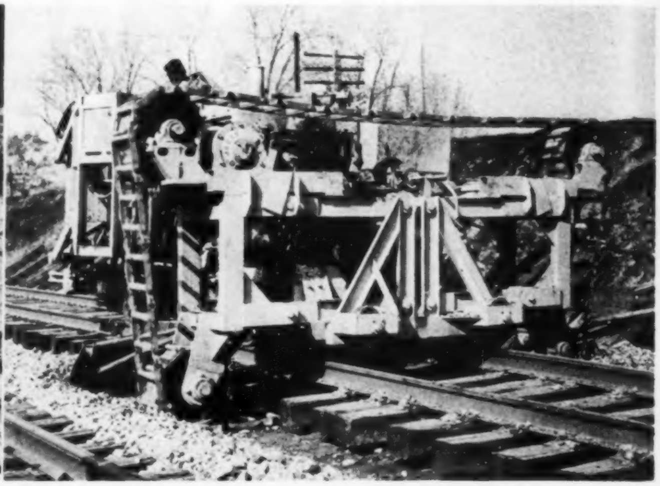
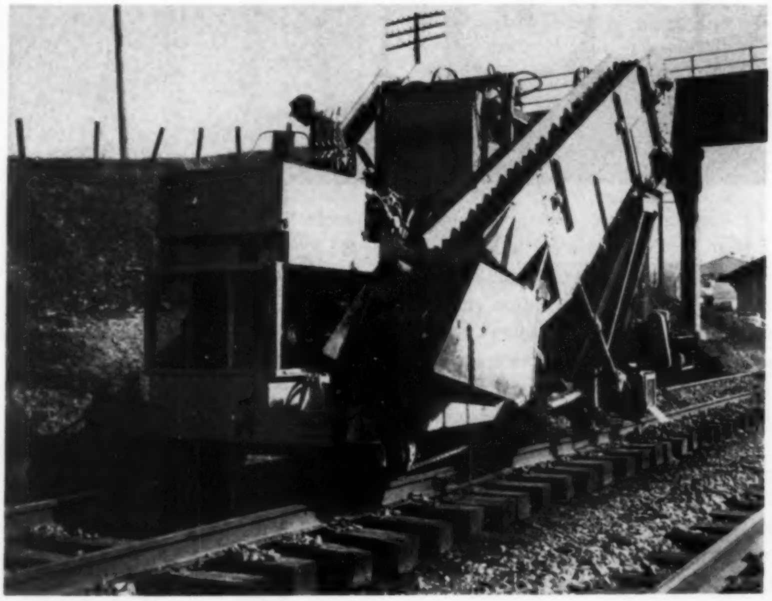
ALUMINUM
If your products call for aluminum tube, it will pay you to put your requirements up to Revere. For at this one source you can obtain virtually any aluminum tube you want . . . seamless drawn, welded, lockseam and others; in an extensive range of sizes, alloys and tempers; both round and other-than-round.
Revere has the men, machines and experience to produce tube that is right for its purpose as well as right on schedule. It will pay you to tie the progress of your business to the most dependable sources of supply. Call the nearest Revere Sales Office now. In all principal cities. Revere Copper and Brass Incorporated. Founded by Paul Revere in 1801. Executive Offices: 230 Park Avenue, New York 17, N. Y.
Revere Aluminum Mill Products include extruded shapes, rod and bar; coiled and flat sheet, embossed sheet, circles and blanks; seamless drawn and welded tube; rolled shapes; electrical conductors; forgings; and foil. Revere is headquarters for tube, and can supply it not only in aluminum but in copper, copper-base alloys and electric welded steel.





MECHANICAL BEDMAKERS on railroads now do the hard work in track maintenance that cuts wear and tear on cars and cargoes. These new units, made by Kershaw Mfg. Co., were recently demonstrated on the Erie road. A Jack-All unit (left) raises rails and ties as much as 7 in. to restore original track elevation, then tamps ballast temporarily to hold the new position. Its two hydraulic rams can be operated independently to provide elevation differences between rails on curves. An undercutter (right) clears up to 5 in. of old ballast from beneath ties. Its cutting chain arms withdraw in 30 seconds to pass traffic on adjacent tracks. Cleaner (below) picks up old ballast, shakes it free of dirt and redistributes the stone under the ties. Gangs of these machines and others will recondition 500 ft of track per hour at 300 per cent labor savings over manual methods.



per cent of the sample replied no. Even among engineers in large companies, the reply was 80 per cent no.

Mechanical Literature Searching Uses Coded Technical Abstracts

CLEVELAND, O.—A method of literature searching which employs a mechanical searching selector and coded abstracts of technical matter has been described in recent technical sessions of the Special Libraries Association by Allen Kent, associate director of the Center for Documentation and Communication Research, Western Reserve University. The method and the equipment are early results of a project financed by the American Society for Metals to determine whether an operating literature searching service is feasible.

Starting point for designing the equipment was the realization that documentation systems are called upon to meet a wide variety of information requirements. These range from narrowly defined specific inquiries to comprehensive descriptions. Further analysis revealed that any given requirement involves a combination of several concepts.

In operating the system, abstracts of technical papers are first converted into a telegraphic form of standardized terminology. Each of the standard terms is then expressed in a code of letters and symbols suitable for posting on punched paper tape.

A requirement for information is expressed the same way the original abstracts were prepared. The Search Selector scans the tape, comparing the requirements with the contents of encoded documents.

Circle 409 on page 19

Where the two match, the selector types the serial number of the document.

For example, an abstract composed in conventional language reads, in part, as follows:

> **Alterations in Cast-Iron Properties Accompanying Use of a Strong Inoculant of the Si-Mn-Zr type.** C. O. Burgess and R. W. Bishop. *Trans. Am. Foundrymens' Assoc.* Preprint No. 44-16, 35 pp. (1944).
>
> A study of the effect of ladle treatment on the Brinell hardness, tensile strength, tranverse strength and chill depth of 2.5 C, 3.0 C, 3.5 C unalloyed gray irons, each group varying in Si content from 1 to 2.5 per cent.

Expressed in standardized telegraphic form, the same abstract reads:

> *Serial No.* 00190190 *Authors* C. O. Burgess and R. W. Bishop. *Trans. Am. Foundrymens' Assoc.* Preprint No. 44-16, 35 pp. (1944). *Field,* Ferrous metallurgy. *Starting material, Material processed, Properties given for* Gray iron *containing* 2.5-3.5 C and 1-2.5 Si. *Properties* Tensile strength, transverse strength, Brinell hardness, chill depth. *Process* Ladle treatment.

Examples of codes for elements of the telegraphic abstract are: DCT/ for "Document reference (namely)" and TRAMFRMAS for "Trans. Am. Foundrymens' Assoc."

Converted to code form, the abstract appears thus:

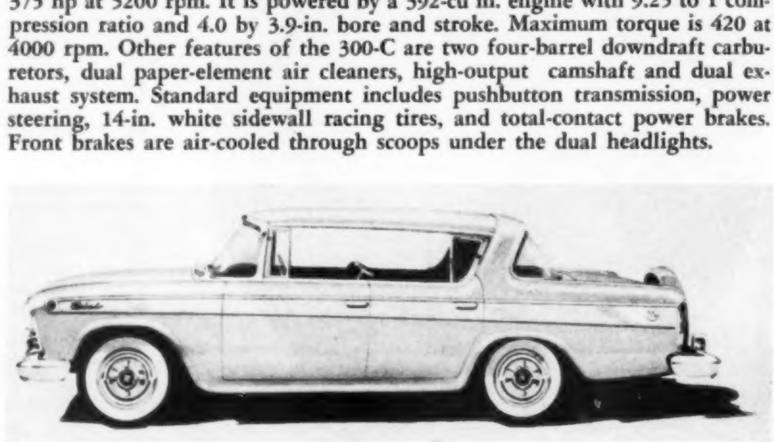
> SN00190190ATR/C. O. BURGESS: R. W. BISHOP DCT/TRAMFR MAS;PPT44-16PP35YR1944LOKSA CNMYTL 01 KALRYRN01KAJKEJ KOVRARN04KUJ&C&/2.5% 3.5% & Si&1 % 2.5% KWVPAPR48PAPR55 PAPRMYTL11.

The standardized terminology is an extension of conventional subject indexing and classification. Combinations of the standard terms permit expression of complex concepts in the same way that words in conventional language form phrases, phrases form sentences, and sentences form paragraphs.

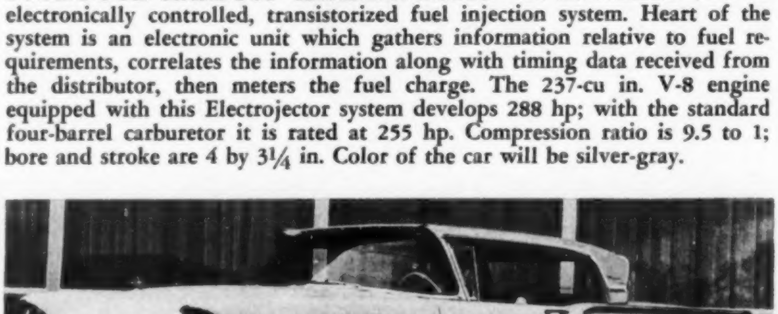
The Searching Selector permits an exceptionally wide range of concepts to be used in defining and conducting searching operations. The scope of a search may be defined not only in terms of

Three More 1957 Automobiles Announced

CHRYSLER MODEL 300-C, a 54.7-in. high sports-type automobile, develops 375 hp at 5200 rpm. It is powered by a 392-cu in. engine with 9.25 to 1 compression ratio and 4.0 by 3.9-in. bore and stroke. Maximum torque is 420 at 4000 rpm. Other features of the 300-C are two four-barrel downdraft carburetors, dual paper-element air cleaners, high-output camshaft and dual exhaust system. Standard equipment includes pushbutton transmission, power steering, 14-in. white sidewall racing tires, and total-contact power brakes. Front brakes are air-cooled through scoops under the dual headlights.



FOUR-DOOR HARDTOP RAMBLER REBEL will be available with an electronically controlled, transistorized fuel injection system. Heart of the system is an electronic unit which gathers information relative to fuel requirements, correlates the information along with timing data received from the distributor, then meters the fuel charge. The 237-cu in. V-8 engine equipped with this Electrojector system develops 288 hp; with the standard four-barrel carburetor it is rated at 255 hp. Compression ratio is 9.5 to 1; bore and stroke are 4 by 3¼ in. Color of the car will be silver-gray.



MERCURY'S TURNPIKE CRUISER introduces a ventilating system comprising roof-level fresh air intakes and a power-operated retractable rear window. Other power equipment includes steering, brakes, windows and Seat-O-Matic, which automatically positions the seat in response to a selection dialed on the instrument panel. The car has Quadri-Beam dual headlamps, air-cushion rear suspension, full-cushion shock absorbers and a clock that automatically computes elapsed time and mileage, permitting rapid calculation of average speed for given distances. Engine is 290 hp with 368 cu in. displacement and compression ratio of 9.75 to 1. Turnpike Cruisers will be made in two and four-door hardtop body styles.

Design data on adhesives

(Advertisement)

Armstrong

ADHESIVES • COATINGS • SEALERS

NUMBER SIX

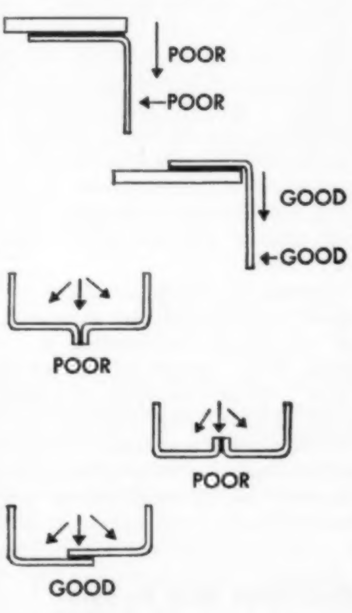
Designing joints for flexible materials

When sheets of flexible materials are to be bonded to metal, the joints should be designed with the adhesive in shear wherever possible. Joints where the adhesive is in peel are generally less desirable and may fail when stress is applied.

In assembling thin gauge sheets to metal, particularly when bonded behind the metal, the sheet should be overlapped as illustrated to place the adhesive in shear. The overlap should be adequate to place minimum unit stress on the adhesive.

The drawings below illustrate plastic or rubber sheet bonded to metal in shear and peel, and flexible plastic bonded to itself.

Stress direction ⟶



For more information

Write for a copy of "Armstrong Adhesives, Coatings, and Sealers." Armstrong Cork Company, 8012 Dean St., Lancaster, Penna.

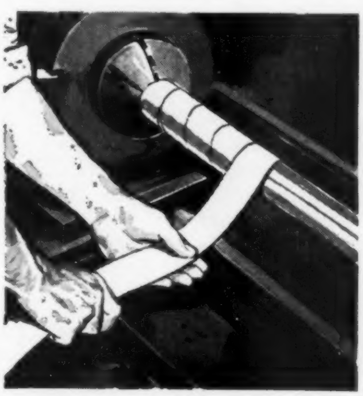
How to bond flexible materials

The first thing to be considered in bonding flexible materials is the design of the joint. Four rules, basic to all adhesive joints, must be observed:

1. Make the bonded area as large as possible.
2. Make the maximum proportion of bonded area contribute to strength.
3. Stress the adhesive in the direction of its maximum strength.
4. Minimize stress in the direction in which adhesive is weakest.

Design in Shear

Adhesives for bonding rubber vary widely from soft, tacky products to rather hard, rigid thermosetting resins. Although the rubbery adhesives generally have good peel properties, joints should be designed in shear rather than in peel where possible, as shear strength is higher.



BONDING FLEXIBLE COVERING to a steel loom roll. Adhesive is spread on the roll which is chucked in a lathe. Covering is taped on at one end, then fed on the roll, which turns at 10 rpm.

To minimize the unit stress on the adhesive, overlap should be adequate when bonding sheets of thin rubber or plastic to metal. And during assembly, tension in the sheets should be kept at a minimum, since it can result in residual constant stress on the adhesive.

Edge-Joining

Edge-joining sheets of thin flexible material may be accomplished by a simple lap joint, or they may be butted and a strap of the same material or of cloth applied over the seam. Butting sheets of heavier gauge is not practical, since butt joints in tension generally have inadequate strength.

Scarf joints have been found to be a practical solution to edge-joining of heavy sheet material. They are especially useful for strips of rubber from 3/16-inch to 3/8-inch thickness or heavier, which often require splicing or fastening to form corners, as, for example, in making gaskets. (Length of a scarf joint in rubber should be at least four times the thickness.)

Heavy Materials

Motor mountings and roll coverings frequently involve the adhesion of heavier sections of rubber or flexible materials to metal. Under severe loading, with rubber roll coverings which allow stress to be translated through the rubber to the adhesive, failures may be minimized by improving stress distribution in the rubber next to the adhesive bond by increasing rubber hardness at the inner diameter, or by using cloth interliners.

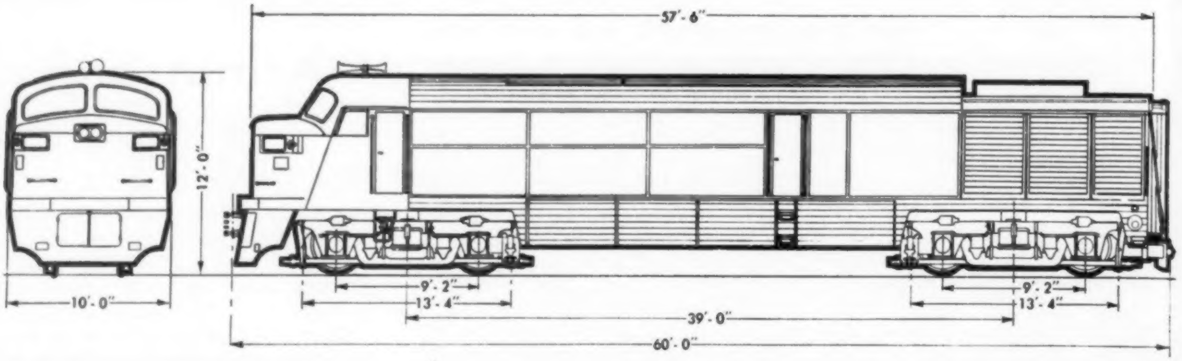
Rubber-to-Metal

In rubber-to-metal or other flexible-rigid assemblies, stress concentrations can be minimized through the elimination of sharp corners. The metal should be thick enough to prevent peel stresses which may occur with thin-gauge metals. Sharp changes in section in the rubber or plastic can also result in stress concentrations.

Loading beyond the capacity of the bonded assembly can result not only in adhesive failures, but also in short life of the assembly due to rubber fatigue and failure. Depending on permissible cost and performance requirements, it may be possible to eliminate over-stressing in some applications by providing a bumper which comes into compression when a given deflection is reached.

Rubber-to-metal assemblies in shear or tension loading may be designed at about 50 psi and in compression at about 250 psi, although these loadings depend to a great extent on the application involved, the type of rubber, and the adhesive.

Circle 410 on page 19



Speed Merchant locomotives at each end of the New Haven's new train between New York and Boston operate on diesel or third-rail electric power.

specific substances, devices, attributes, processes, conditions, organisms, persons, locations, etc., but also in terms of generic concepts and their relationships to specific terms.

Fuel Production to Double In Twenty Years

NEW YORK, N. Y.—Production of fuels in America will double in the next 20 years, according to Dr. Clyde Williams, president and director of Battelle Memorial Institute. Dr. Williams recently told members of the ASME that coal production will reach one billion tons by 1975 and that increased demand will result in greater use of synthetic liquid fuels and fuel gas manufactured from coal and shale.

Factors contributing to future demand are:

1. Population increase. The Census Bureau forecast for 1975 is 228 million.
2. Improved standard of living. Gross national product should reach $870 billion by 1975, more than double the present $414 billion.
3. New methods of production and fabrication requiring more energy per unit of weight or volume. Production of aluminum requires more energy than many of the materials it is replacing. Synthetic building materials, plastics and fibers use more energy than natural materials.
4. Increased electrification of homes, offices, factories and farms.
5. Increased mechanization and other changes in processing in the iron and steel industry.

Paired Engines Push-Pull Double-Ended Shuttle Train

NEW HAVEN, CONN.—A new five-car train of the Talgo type has been placed in service by the New York, New Haven and Hartford Railroad on the run between Boston and New York. Named the Daniel Webster, the train has locomotives at both ends.

The train can be reversed at the ends of its run without actual turning around, as on loop track, or without uncoupling the locomotives. Also, at the New York end, the locomotives are convertible from diesel power to third-rail electric power.

General data for the locomotives are:

Weight	
Total fully loaded (lb)	216,000
Total on drivers (lb)	110,000
Per axle (lb)	55,000
Performance	
Starting tractive effort @ 30% adhesion (lb)	33,000
Continuous rated tractive effort @ 23.5 mph (lb)	15,000
Maximum speed (mph)	117
Minimum radius of curvature (ft)	212

Prime mover in each locomotive is an eight-cylinder Fairbanks Morse opposed-piston diesel engine. The engine drives a main traction generator through a flexible coupling. The diesel engine is operated at constant speed of 850 rpm and variable load. The application is analagous to a stationary steam power plant.

In contrast to the majority of diesel-electric locomotives operating on domestic railroads, the engine-room space is a pressurized plenum chamber and is used to supply the air requirements of the engine, the self-ventilated main generator and the air compressor.

Provision of the plenum chamber is considered to be highly pertinent in the case of the trailing locomotive which encounters the dust or snow raised from the roadbed by the leading locomotive and the cars.

Two GE-752 motors are used for traction purposes on each locomotive. For third-rail applications the standard motor is slightly modified by the addition of a ground return current path to bypass the 600-volt propulsion current around the locomotive journal bearings.

During third-rail operation, automatic resistor control is provided for smooth acceleration in 12 steps under control of a current relay. While this type of equipment is commonly used on multiple-unit cars operating on third-rail power, this is believed to be its first use on road locomotives in the U.S.

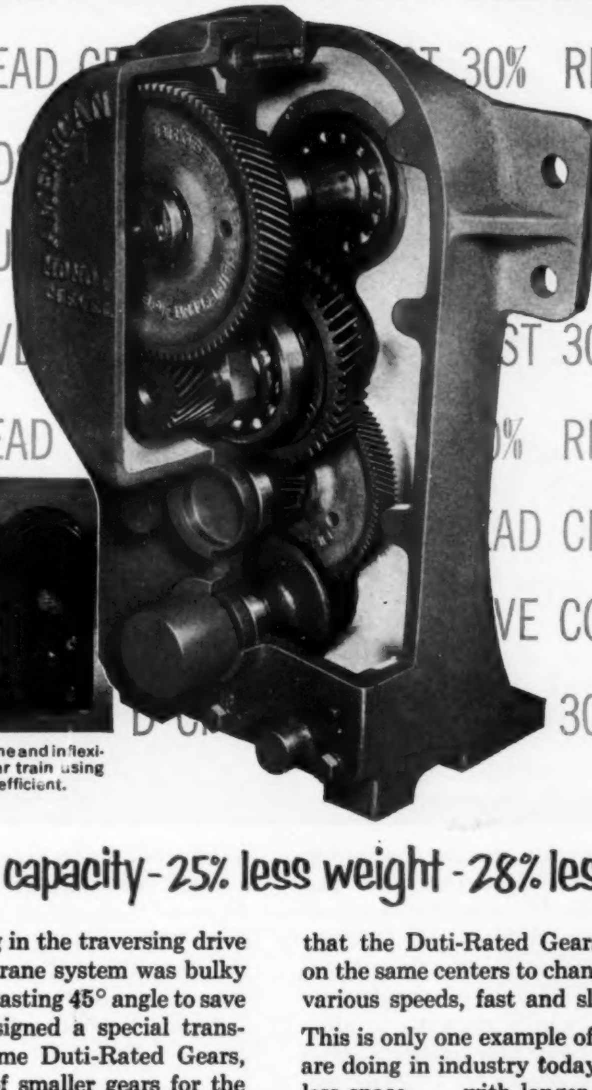
Atom Arms Must Be Built Sure-Fire and Maintainable

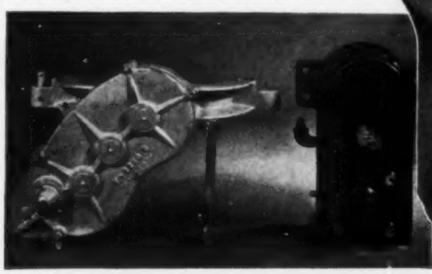
NEW YORK, N. Y.—"Atomic war has not been stalemated to the degree that we can afford to tailor our military forces primarily to the requirements of limited or little wars." This was the advice of Air Force Secretary Donald A. Quarles, speaking at the recent annual

(Continued on Page 22)

Duti-Rated Lifetime Gears

REDUCE OVERHEAD CRANE DRIVE COST 30%





Old gear train at left is large, cumbersome and inflexible. At right Foote Bros., designed gear train using Duti-Rated Gears—compact, light and efficient.

100% more capacity - 25% less weight - 28% less size

Ordinary commercial gearing in the traversing drive for an overhead, traveling crane system was bulky and had to be set at a space wasting 45° angle to save head room. Foote Bros. designed a special transmission system using Lifetime Duti-Rated Gears, permitting the application of smaller gears for the same capacity, allowing shorter center distances and a much more compactly designed drive.

The savings in space not only improved the design and performance of the overhead crane but also life expectancy. Maintenance requirements were greatly reduced. An outstanding feature of the new drive was that the Duti-Rated Gears could be interchanged on the same centers to change the ratios . . . allowing various speeds, fast and slow, for traversing.

This is only one example of what Duti-Rated Gears are doing in industry today. Extra gear capacity in less space . . . with longer life and lower costs . . . could be important to you, too. Call Foote Bros. today and learn all the advantages of Duti-Rated Lifetime Gearing . . . pre-engineered as standard or designed for your application. *FREE! Foote Bros. Engineering Manual "Duti-Rated Lifetime Gearing". Write for your copy today!*

This trademark stands for the finest industrial gearing made!

FOOTE BROS Duti-Rated® LIFETIME GEARING

T.M. Reg. U.S. Pat. Off.

FOOTE BROS.

Better Power Transmission Through Better Gears

Foote Bros. Gear and Machine Corporation

4545 South Western Blvd., Dept. O, Chicago 9, Ill.

Circle 411 on page 19

Circle 412 on page 19

Reader Information Service

SUBJECT INDEX

Editorial and Advertising content classified by subject and listed by page number for convenience when studying specific design problems. For further information on subjects advertised, refer to advertisement and circle Item Number on a Yellow Card—following page.

MACHINE DESIGN is indexed in Industrial Arts and Engineering Index Service, both available in libraries, generally

SUBJECT INDEX (continued)

USE A YELLOW CARD *for More Information . . .*

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

Index to New Parts & Helpful Literature

BY ITEM NUMBERS

HELPFUL LITERATURE—descriptions start on page 98

NEW PARTS & ENGINEERING EQUIPMENT— descriptions start on page 104

MACHINE DESIGN
DEC. 27, 1956

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401	426	451	476	501	526	551	576	601	626	651	676	701	726	751
402	427	452	477	502	527	552	577	602	627	652	677	702	727	752
403	428	453	478	503	528	553	578	603	628	653	678	703	728	753
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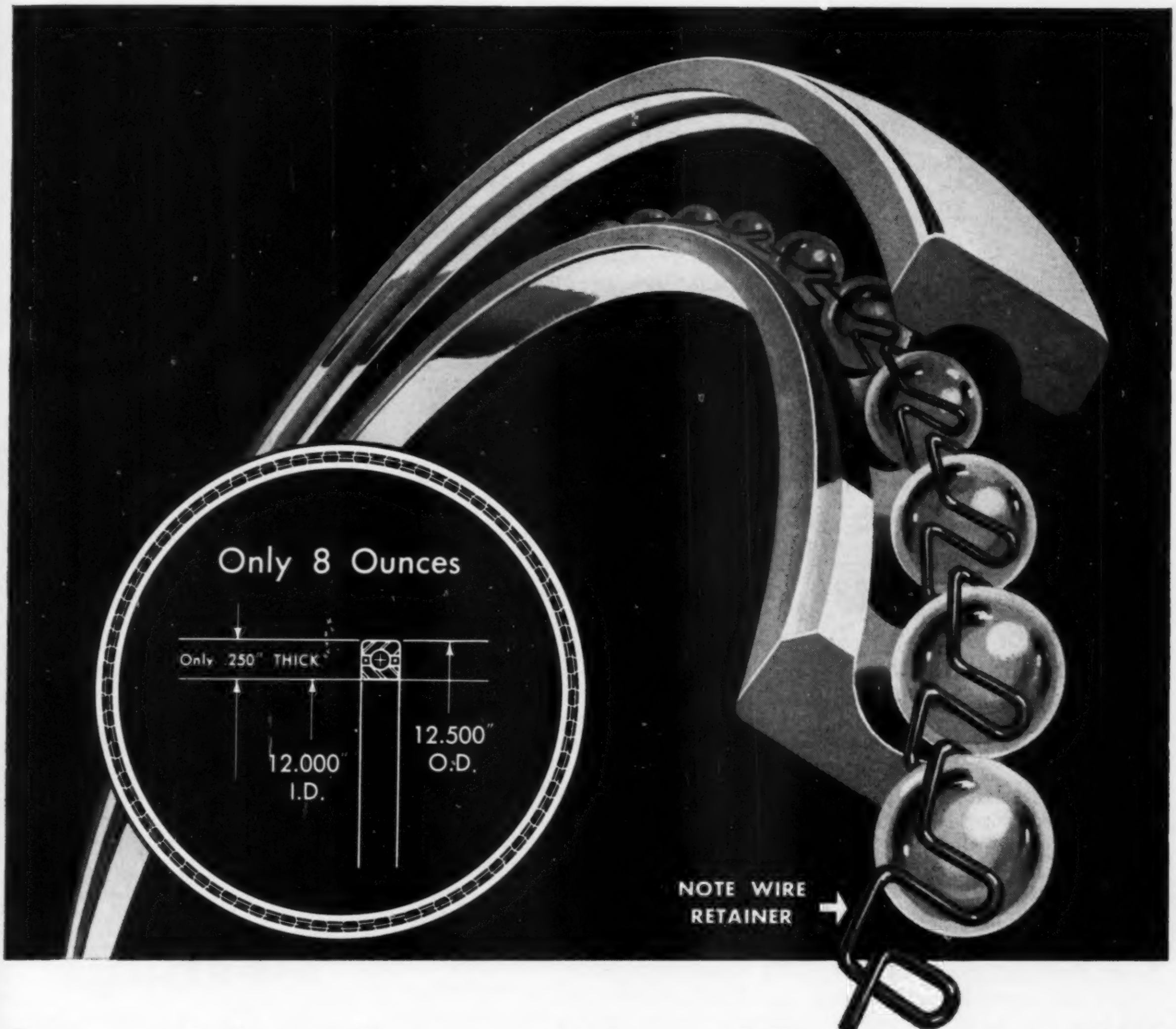


Save weight and space with world's thinnest radial ball bearings—*Reali-Slim* by Kaydon

HERE it is! A *Reali-Slim* radial ball bearing with a wire separator that has just short of a full complement of balls for maximum capacity. What's more, you still get all the advantages of a separator between the balls. This design also gives you a bearing that's light-in-weight and is, without a question, the thinnest bearing ever built in this diameter.

Whatever your product design, there's a small or large diameter *Reali-Slim* bearing that can be the right answer to your thin-section bearing problems.

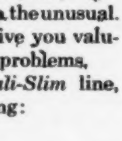
The radial ball bearing, illustrated here, is *really slim* — 12.000" I.D., 12.500" O.D., .250" thick . . . *and weighs only eight ounces.* It has 9,810 lbs. static load capacity, 1,256 lbs. at 100 rpm. Kaydon is able to produce *Reali-Slim*, high-precision bearings because Kaydon specializes in the unusual.

Kaydon bearing engineers are prepared to give you valuable help with technical, thin-section bearing problems.

For detailed information on Kaydon's *Reali-Slim* line, ask for engineering catalog No. 54-RS3 detailing:

Reali-Slim Ball Bearings — Conrad, angular contact and 4-point contact types in seven standard cross sections from $\frac{1}{4}$" to 1.000" and in bore diameters from 4" to 40".

Reali-Slim Roller Bearings — Radial and taper roller types in cross sections from $\frac{9}{16}$" and in bore diameters from 5" to 40".



THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

K-561

All types of ball and roller bearings — 4" bore to 120" outside diameter . . .

Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Spherical Roller • Ball Radial • Ball Thrust Bearings

Circle 413 on page 19

(*Continued from Page* 14)

meeting of the ASME. Secretary Quarles also told the engineers that design objectives in the increasingly complex weapons for atom-scale war must be reliability and maintainability. He said that keeping adequate numbers of competent maintenance technicians was as much a problem as keeping the quality lead in the weapons themselves.

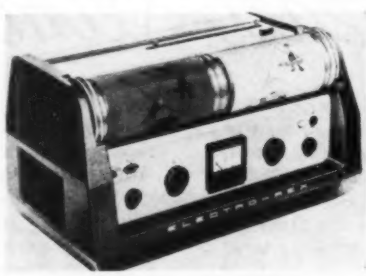
"Any thought," he said, "that under present conditions nations will rule out nuclear war, or any other kind of war, on moral grounds ignores the lessons of history, some of which are recent history. Such a delusion could result in undermining our retaliatory position to a point that might tempt an aggressor to strike us in the hope of achieving a quick and favorable decision."

The U.S. now has a clear margin of qualitative superiority over Communist military strength, thanks to "our very gratifying success in meeting high standards for people and hardware." He added, however, that the problem of qualitative superiority in operations people is not so clear-cut or so widely understood as the problem of maintaining an edge in weapons and equipment.

He urged engineers to help maintain a proper balance between operating skill and hardware by designing as much reliability as possible into new equipment and by making the equipment as simple as possible consistent with performance requirements.

He pointed out that the F-89 interceptor uses enough tubes or transistors for 80 home radios and that the B-47 contains a complex of 14 electronic systems.

"In this light," he said, "we begin to understand that achieving the full potential of modern weaponry depends not only on the scientist that lays the groundwork for it, and the engineer that designs it. It also depends finally and critically on the individual technician — on his skill, experience, and devotion to the job of keeping it in operation."



PHOTOS CAN BE COPIED on office duplicators, offset or mimeograph type, with stencils prepared on this new machine. An optical scanning system in the Electro-Rex stencil cutter converts images to high frequency current which is amplified electronically and transferred to the reproduction side of the drum. Scanning definition from 125 to 750 lines per in. is claimed attainable.

Carbon tetrachloride users are warned that they are handling a deadly poison, according to an article in the December *Readers Digest*. Vapors of CCl_4 attack the nervous system, kidneys, intestines and liver. Generous amounts of the material are used daily in drawing rooms to clean drafting tools.

Meetings

AND EXPOSITIONS

Jan. 14-18—

Society of Automotive Engineers Inc. Annual Meeting to be held at the Sheraton-Cadillac and Statler Hotels, Detroit. Further information can be obtained from society headquarters, 485 Lexington Ave., New York 17, N. Y.

Jan. 16-18—

Society of Plastics Engineers Inc. Thirteenth Annual National Technical Conference to be held at the Hotel Sheraton-Jefferson, St. Louis. Further information can be obtained from society headquarters, 34 E. Putnam Ave., Greenwich, Conn.

Jan. 17-18—

Engineers Joint Council General Assembly to be held at the Statler


Machine Tools And Power Transmission Equipment
STYLE GU — A packaged sealing unit containing both rotating and stationary seal faces enclosed in metal housing. Stock sizes for shafts .250 through 4.000.
Pumps And Compressors
ROTO-FLEX — Rugged flexibility. Only 3 parts. Single or double units. Stock sizes for shafts .250 through 4.000.
STYLE RFO — A specially designed Roto-flex seal, for installation outside the stuffing box. Stock sizes for shafts .250 through 4.000.
A Complete Line
GITS SHAFT SEALS
For Every Application
These modern, mechanical, face-type seals are carried in stock — to save you time and money. Write for detailed data.
GITS BROS. MFG. CO.
1868-A South Kilbourn Avenue • Chicago 23, Illinois
Specialists In Lubricating Devices And Shaft Seals For Almost Half-A-Century
Heavy Machine Tools
STYLE DPC — A high-speed, carbon-faced seal, for more compact installation in heavy industrial machinery. Stock sizes for shafts .250 through 4.000.
Household Appliances
STYLE SGU—A factory-assembled unit-type seal for the small-budget user. Stock sizes for shafts .250 through 1.000.
Aircraft Engines And Accessories
STYLE HH — Absolute minimal space (both radial and axial) under extreme conditions of temperature, pressure and seal face surface speed. Features pressure balance when fluid pressure is applied internally or externally. Stock sizes for shafts .250 through 4.000.
Circle 415 on page 19

Circle 416 on page 19

News Roundup

Hotel, New York. Further information is available from council headquarters, 29 W. 39th St., New York 18, N. Y.

Jan. 21-22—
Solar Furnace Symposium to be held at Hotel Westward Ho, Phoenix, Ariz. Sponsors are the Association for Applied Solar Energy, Stanford Research Institute, Arizona State College and the University of Arizona. Further information can be obtained from Mr. John I. Yellott, 3424 N. Central Ave., Phoenix, Ariz.

Jan. 21-25—
American Institute of Electrical Engineers. Winter General Meeting to be held at the Hotel Statler, New York. Further information is available from AIEE headquarters, 33 W. 39th St., New York 18, N. Y.

Jan. 28-31—
Plant Maintenance and Engineering Show to be held at the Cleveland Public Auditorium. Further information can be obtained from Clapp & Poliak Inc., 341 Madison Ave., New York 17, N. Y.

Feb. 5-7—
Society of the Plastics Industry Inc. Twelfth Annual Technical and Management Conference of the Reinforced Plastics division, to be held at the Edgewater Beach Hotel, Chicago. Further information is available from society headquarters, 250 Park Ave., New York 17, N. Y.

Feb. 15-16—
National Society of Professional Engineers. Spring Meeting to be held at Hotel Francis Marion, Charleston, S. C. Further information is available from society headquarters, 2029 K St., N. W., Washington 6, D. C.

Feb. 24-28—
American Institute of Mining, Metallurgical and Petroleum Engineers. Annual Meeting to be held at the Hotel Jung, New Orleans. Additional information can be obtained from the institute's headquarters, 29 W. 39th St., New York 18, N. Y.

Circle 417 on page 19

MEN

OF MACHINES

Sidney L. Eastman has been appointed vice president in charge of engineering by Cleveland Worm & Gear Co., Cleveland. Mr. Eastman joined the company as an engineer in the test laboratory in 1927. He

Sidney L. Eastman

next served as district manager in Detroit, then as assistant sales manager. In 1940 he was named assistant chief engineer. Mr. Eastman was promoted to chief engineer four years later and held that position at the time of his new appointment.

The election of **Henry M. Haase** to vice president in charge of engineering and research has been announced by Borg-Warner Corp., Chicago. He will direct the firm's program of product planning and engineering research and development, including general supervision of the new Research Center in Des Plaines, Ill. and the Petro-Mechanical Research Div. in Los Angeles.

William Alvarez has been named manager of engineering for General Electric's Industry Control Dept., Roanoke, Va. Mr. Alvarez joined the company in 1940, completed the G-E test course, and

Circle 418 on page 19

Men of Machines

was assigned to the engineering section of the Control Div. In 1952 he was appointed manager of advance engineering in the Industry Control Dept. Earlier this year he was named acting manager of engineering.

The Indiana Steel Products Co., Valparaiso, Ind., has announced the appointment of **James R. Ireland** as director of research and engineering. Mr. Ireland joined the firm as director of research in

James R. Ireland

October, 1953. He was previously chief engineer of Thomas and Skinner Steel Products and an engineer in the Magnetic Materials Dept. of Western Electric Co. Mr. Ireland is the author of the article "Permanent Magnets," which appeared in the April, 1949 issue of MACHINE DESIGN.

Donald C. Erdman has been appointed assistant to the president of Sperry Products Inc., Danbury, Conn. Mr. Erdman was formerly president and chief engineer of Electro Circuits Inc.

Motorola Inc., Chicago, recently announced a number of new assignments. **Jack Davis,** former radio products manager, was named vice president for consumer products engineering. He is succeeded by **Fred Williams,** former home radio chief engineer. **Robert Trojan,** former project engineer for

Circle 419 on page 19

home radio, replaces Mr. Williams. **Henry Magnuski,** former chief engineer of the applied research department, was named staff scientist to the executive vice president. **Roy Olson,** previously director of engineering of the Microwave and Industrial Control Dept., is now manager of that department, and **Angus MacDonald** is director of engineering. He was assistant director of engineering of the C & E Div. **William Firestone,** former assistant chief engineer of the applied research department of the C & E Div., was named chief engineer. **William Weisz,** former product manager of portable products, is now chief engineer for two-way radio and portable products.

W. H. Bennett has been named president of the Hydraulic Press Mfg. Co., Mount Gilead, O., a division of Koehring Co. Mr. Bennett, who joined H-P-M in 1939, has held various positions in the company, including that of director of engineering.

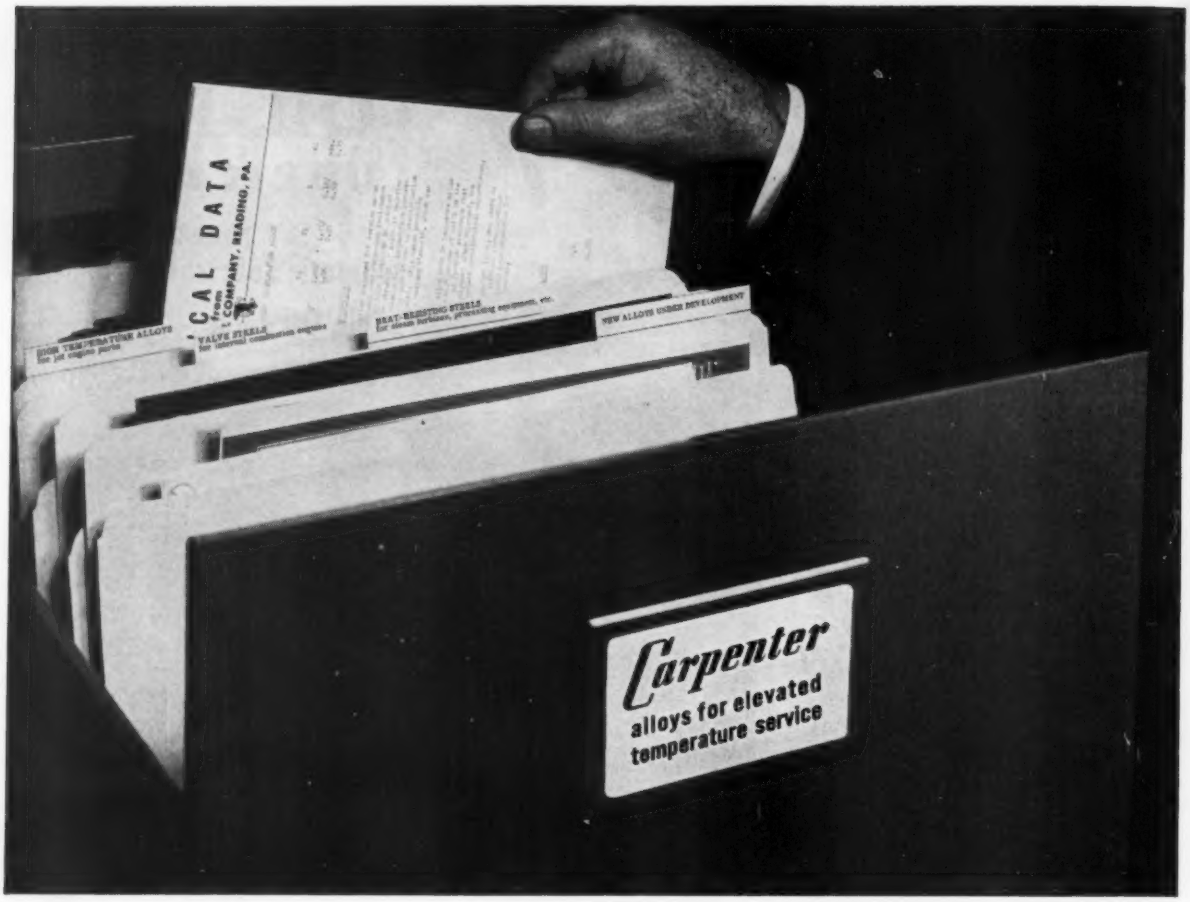
The Semiconductor-Components division of Texas Instruments Inc., Dallas, Tex., has appointed **J. N. Carman** chief mechanical engineer. Mr. Carman was manager of the engineering department of Pacific Semiconductors Inc. Previously, he had been associated with Hughes Aircraft Co. and General Electric Co.

Edward McClaud has been appointed chief engineer in charge of product, process and tool engineering by Parker Stamp Works, Hartford, Conn. Mr. McClaud, who was formerly associated with Pratt & Whitney Aircraft, joined Parker last January.

Richard J. Brown has joined Crescent Metal Products Inc., Cleveland, as chief engineer. He was chief engineer at Perfection Industries Inc.

Jack W. Qualman has been appointed assistant chief engineer of the Detroit Transmission Div. of General Motors Corp., Ypsilanti, Mich. He will direct future product design and development.

Circle 420 on page 19



Discover how these ELEVATED TEMPERATURE ALLOYS can give you

√ Improved Forgeability √ Greater Uniformity √ Cleaner Steels

Exciting possibilities for improvement are ahead when you look into the line of Carpenter alloys for parts or products in elevated temperature service. Here is a line of high temperature and heat-resisting alloys produced in a *specialty* mill. Only a true specialty mill can produce so well these very difficult-to-make alloys.

Here, too, is a combination of unusual advantages not normally found in this type of alloys. For example, Carpenter pioneered the addition of rare earth elements to the analyses of certain grades to give you improved forgeability. And Carpenter's unsurpassed, meticulous quality controls, assure you steels with greater uniformity and extra cleanness to meet the strictest inspection requirements.

Whether you work with one of our present elevated temperature alloys, or a steel produced specifically for your own application, you'll find that Carpenter's wealth of fabricating and working information will help you substantially reduce production costs and get better parts.

Outline your plans or problems to your Carpenter Representative or write direct. You'll get the kind of help that pays off with definite improvements. *The Carpenter Steel Co., 120 W. Bern St., Reading, Pa.*

Specify Carpenter alloys for elevated temperature service and get these three big advantages . . .

Improved Forgeability
Greater Uniformity
Cleaner Steel

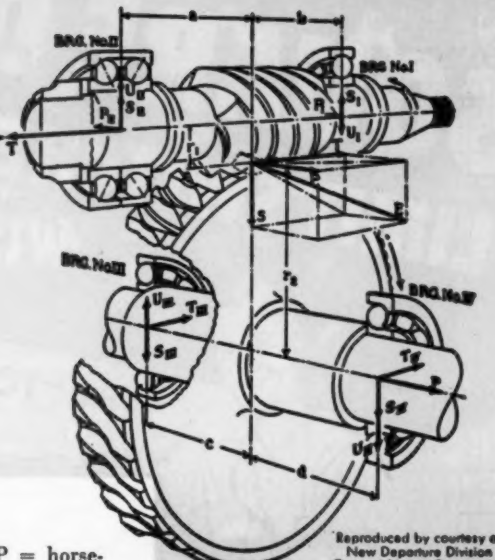
Carpenter STEEL

Improved Alloys for Elevated Temperature Service

Circle 421 on page 19

Helpful Data from
DE LAVAL

How to Calculate Worm Gear Bearing Loads



Reproduced by courtesy of
New Departure Division
General Motors Corporation

$Q = \dfrac{HP \times 63025}{N}$ = TORQUE INPUT to worm, lbs. inches; HP = horsepower transmitted and N = rev. per min. of worm

$P = \dfrac{Q}{r_1}$ = TANGENTIAL FORCE of worm, where

r_1 = Pitch radius of worm in inches
[r_2 = Pitch radius of worm gear
$= \dfrac{1}{2\pi}$ (number of teeth in gear x axial worm pitch)]

$S = \dfrac{P \tan \alpha}{\tan \gamma}$ = SEPARATING FORCE, where
α = Axial tooth pressure angle*
γ = Helix or lead angle of worm*
$= \tan^{-1} \dfrac{\text{lead}}{2\pi r_1}$, or $\tan^{-1} \dfrac{\text{Number of threads x axial worm pitch}}{2\pi r_1}$

$T = \dfrac{P}{\tan \gamma}$ = WORM THRUST, or tangent force driving worm gear

* LEAD ANGLE 0°-35° use 27½° Pressure Angle
LEAD ANGLE 35°-45° use 30° Pressure Angle

BEARING LOADS

Due to	on Brg. I	on Brg. II
P	$P\dfrac{a}{a+b} = P_I$	$P\dfrac{b}{a+b} = P_{II}$
S	$S\dfrac{a}{a+b} = S_I$	$S\dfrac{b}{a+b} = S_{II}$
T	$T\dfrac{r_1}{a+b} = U_I$	$T\dfrac{r_1}{a+b} = U_{II} = U_I$
Total Rad. Load	$\sqrt{P_I^2 + (S_I - U_I)^2}$	$\sqrt{P_{II}^2 + (S_{II} + U_{II})^2} = R_{II}$
Thrust Load		T
Total Load	$\sqrt{P_I^2 + (S_I - U_I)^2}$	$\sqrt{R_{II}^2 + T^2}$
Due to	**on Brg. III**	**on Brg. IV**
P	$P\dfrac{r_2}{c+d} = U_{III}$	$P\dfrac{r_2}{c+d} = U_{IV} = U_{III}$
S	$S\dfrac{d}{c+d} = S_{III}$	$S\dfrac{c}{c+d} = S_{IV}$
T	$T\dfrac{d}{c+d} = T_{III}$	$T\dfrac{c}{c+d} = T_{IV}$
Total Rad. Load	$\sqrt{T_{III}^2 + (U_{III} - S_{III})^2}$	$\sqrt{T_{IV}^2 + (S_{IV} + U_{IV})^2} = R_{IV}$
Thrust Load		P
Total Load	$\sqrt{T_{III}^2 + (U_{III} - S_{III})^2}$	$\sqrt{R_{IV}^2 + P^2}$

Speed Change

$$\text{Gear rpm} = N \times \frac{\text{Number of threads in worm}}{\text{Number of teeth in gear}}$$

For simplicity in bearing load computations for worm gearing, the normal tooth force E is treated in terms of its three perpendicular elements, namely, P, the tangential driving force at pitch radius of worm; S, the force tending to separate worm from the gear, due to the pressure angle; and T, the thrust produced by the lead or helix angle of the worm.

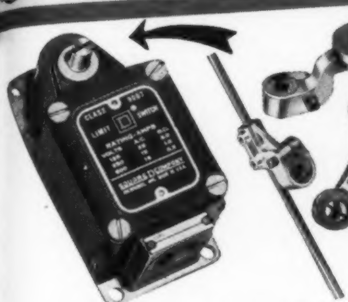
If you have a problem in the selection or application of worm gearing, De Laval engineers will be glad to put their experience to work for you. Either write us giving complete details, or consult your local De Laval representative.
De Laval Steam Turbine Company, 858 Nottingham Way, Trenton 2, New Jersey

XUM

that Mean Plenty

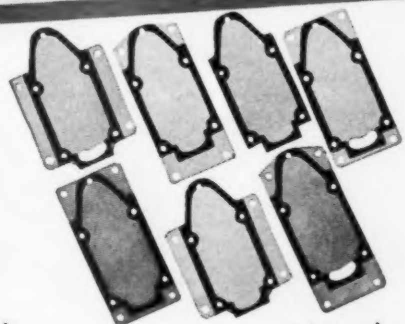
...AND TO THOSE WHO BUY THEM

Just as you'd suspect, it's Square D's consistent performance and long life that appeals most to the men who buy and maintain the machines. But there are other advantages, too, having to do with versatility, easier installation and simpler maintenance. Some of the more important ones are illustrated below.



Simplified stacking because basic switches and a wide variety of lever arms are packaged separately. Moderate stock handles a multitude of combinations.

Continuously adjustable operating lever arms permit an infinite number of adjustments! Up to 80° overtravel reduces arm breakage.



Easy mounting and interchangeability through wide variety of base plates and side mounting holes.

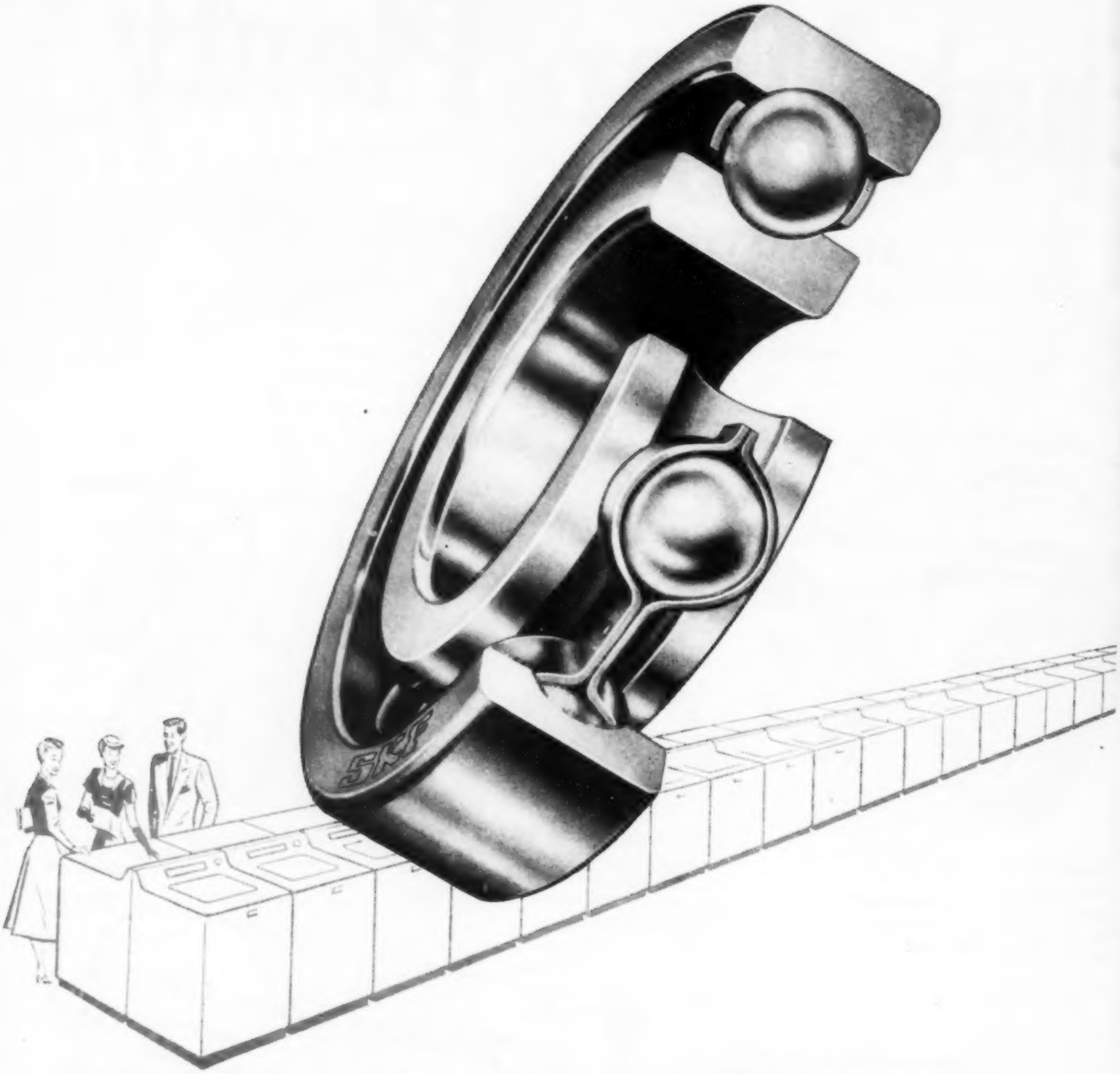
Roller arms are available in a wide range of designs and lengths.

***Write* for Bulletin 9007**

... which gives the details of Square D's complete line of oil-tight limit switches. **Address Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin.**

Everybody's Ahead with Square D!

Circle 422 on page 19



Quiet, smooth, perfect performance...

in home laundry equipment using SKF* ball bearings

Leading manufacturers of home laundry equipment (names on request) rely on SKF Single Row, Deep Groove Ball Bearings for quiet, smooth-running performance.

Whatever your product, it will pay you, too, to switch to SKF anti-friction bearings and get the *plus values* which are built into every one. 7730

SKF—EVERY TYPE—EVERY USE

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- *Ball Bearings*
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- *Tapered Roller Bearings* ("Tyson")

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"Tyson Bearing Corporation

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

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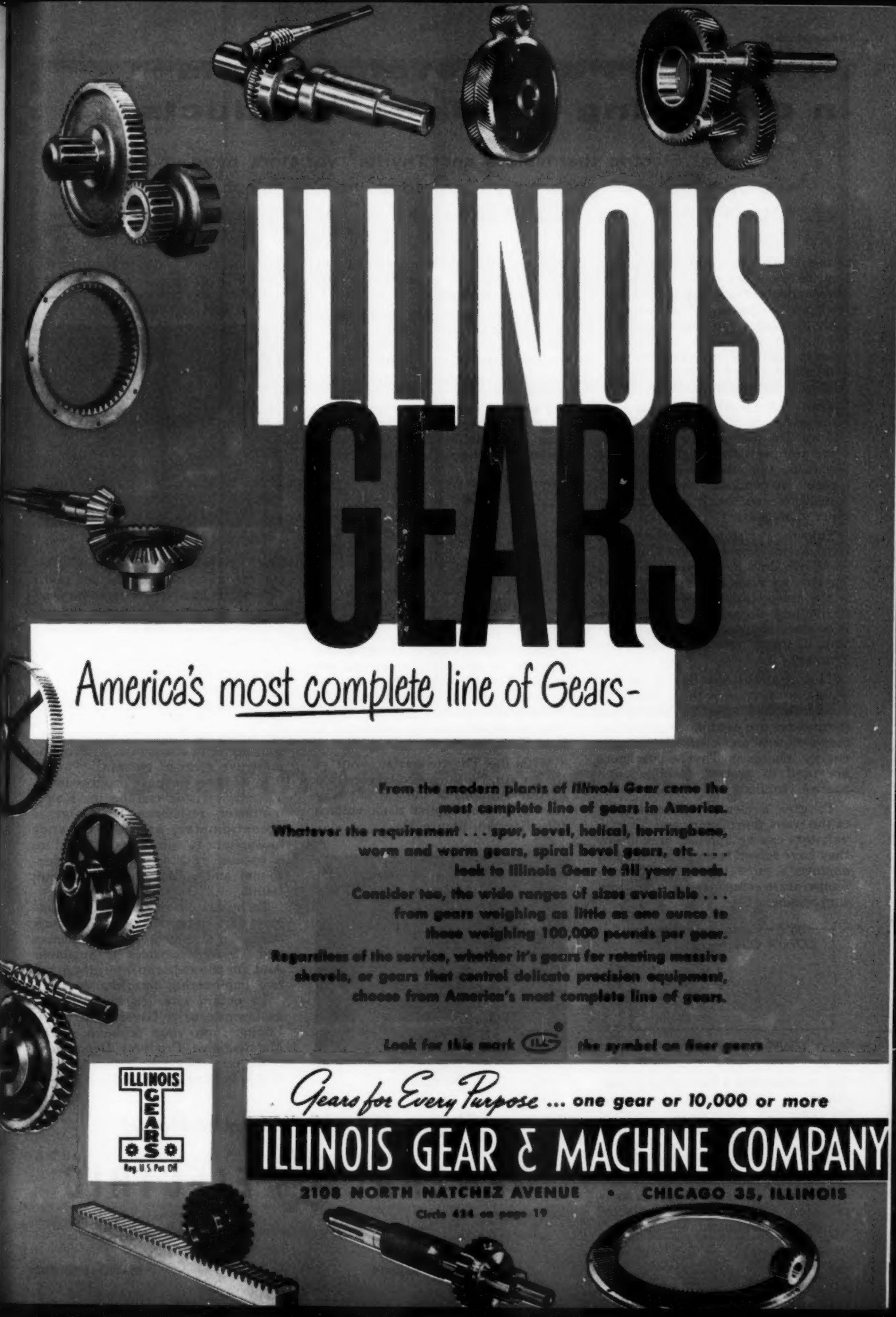
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GEARS
America's most complete line of Gears-
From the modern plants of Illinois Gear come the most complete line of gears in America.
Whatever the requirement . . . spur, bevel, helical, herringbone, worm and worm gears, spiral bevel gears, etc. . . . look to Illinois Gear to fill your needs.
Consider too, the wide ranges of sizes available . . . from gears weighing as little as one ounce to those weighing 100,000 pounds per gear.
Regardless of the service, whether it's gears for rotating massive shovels, or gears that control delicate precision equipment, choose from America's most complete line of gears.
Look for this mark the symbol on finer gears
ILLINOIS GEARS
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Gears for Every Purpose ... one gear or 10,000 or more
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Circle 424 on page 19

(Advertisement)

New trends and developments in designing electrical products . . .

General Electric thermistors and Thyrite* varistors have unique properties that apparently contradict normal electrical laws. Here's how they can be harnessed to improve your product.

General Electric thermistors and Thyrite varistors are ceramic-like semiconductor resistance materials. Each has unique properties – apparently disobedient to normal physical laws – that enable it to perform tasks in electrical and electronic circuits which otherwise would require costly, complex components.

The distinguishing feature of thermistors is their *thermal* sensitivity. Thermistors have large *negative* temperature coefficients of resistance (i.e., their resistance decreases tremendously when heated, instead of increasing slightly like other materials).

Thyrite varistors, on the other hand, are *voltage*-sensitive. Contrary to Ohm's law, a current through a Thyrite varistor varies as a *power* of the applied voltage (i.e., doubling the voltage through a Thyrite varistor can increase the current from 15 to 25 times, instead of the normal 2 times).

The applications based on the unique properties of these materials are almost limitless. In general terms, thermistors are used in the detection, measurement, and control of minute energy changes; Thyrite varistors are used to protect, stabilize, and control circuits.

To give a clearer understanding of the ways thermistors and Thyrite varistors can be applied, here's how they have solved two of the electrical engineer's most vexing problems – temperature compensation and surge suppression.

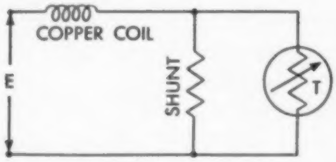

FIGURE 1 — Typical thermistor temperature-compensation circuit

The resistance of a conventional conductor is so affected by ambient temperatures that steady current flow cannot be maintained. For example, as the temperature of copper swings from −60° C to +80° C, the resistance increases 53%.

However, when the copper is compensated with a properly selected thermistor, the maximum deviation from the total average resistance at 25° C is only 3½% – despite the 140° swing in temperature.

In the circuit in Fig. 1, the thermistor's negative temperature coefficient of resistance offsets the positive temperature coefficient of the copper to stabilize current flow. In other circuits, thermistors can be utilized for signal and warning devices, sequence switching, and other time delay applications, because of the inherent thermal inertia involved.

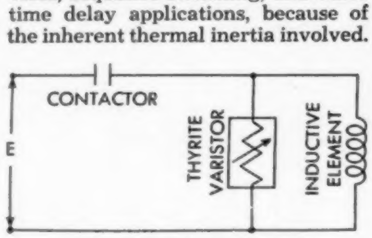

FIGURE 2 — Thyrite varistor surge voltage suppression circuit

Sudden interruptions of inductive circuits cause surge over-voltage, arcing, and high-frequency oscillations – all of which can cause trouble. The circuit in Figure 2 shows how a Thyrite varistor can be connected to hold these effects within safe limits.

With the Thyrite varistor out of the circuit, the surge voltage caused by interruptions of the current may rise to 9 times applied peak voltage (Oscillogram, Figure 3).

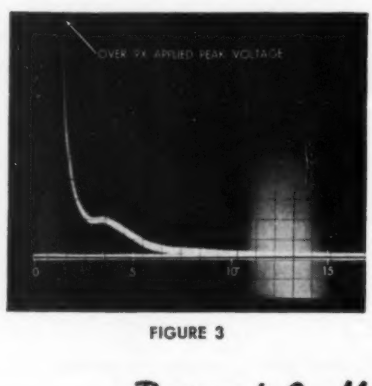

FIGURE 3

But with the Thyrite varistor in the circuit, (Figure 4), the surge voltage is limited to less than 3 times the normal applied peak voltage.

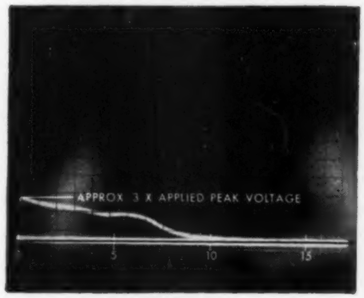

FIGURE 4

The Thyrite varistor draws negligible current at rated voltage, yet offers sufficiently low resistance at the peak current to limit the surge voltage to a safe value and to reduce arcing. Also, the Thyrite varistor quickly discharges circuit energy by providing increasingly higher resistance as the inductive current decays.

If a linear resistor were used to provide the same voltage suppression level, it would have to draw a current equal to more than 30% of the inductive element current.

In addition to surge suppression, a Thyrite varistor can be used as a nonlinear resistance parameter, a potentiometer, and a frequency multiplier. It can also be used as a bypass resistor to protect personnel and equipment from circuit faults.

Technical literature giving complete data on properties, applications, sizes, and shapes of G-E thermistors and Thyrite varistors is available. And, for the experimenter, there are two engineering test kits on each.

To obtain kits, literature, or the assistance of a General Electric Engineer on your problem, write: *Metallurgical Products Department of General Electric Company, 11126 E. 8 Mile Street, Detroit 32, Michigan.*

Progress Is Our Most Important Product

GENERAL ELECTRIC

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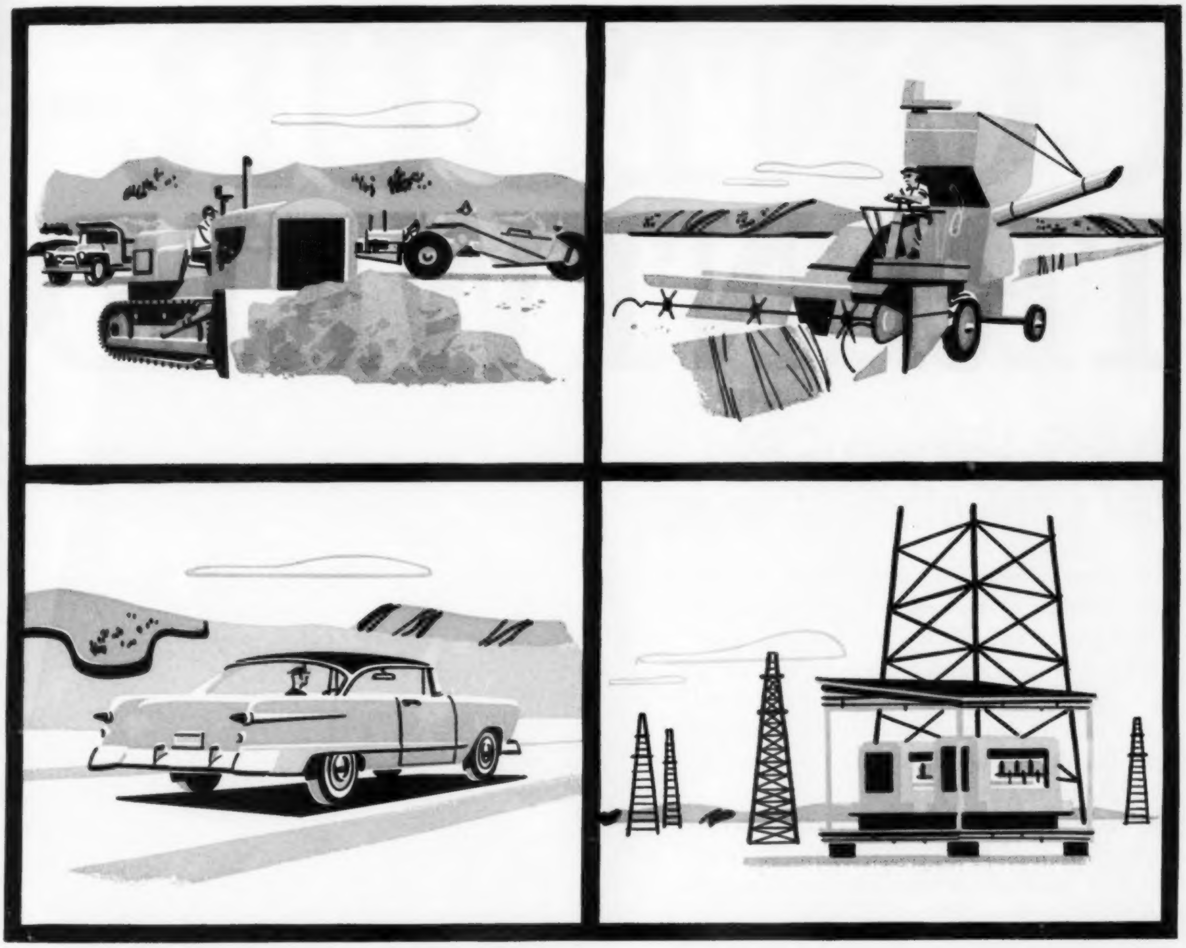
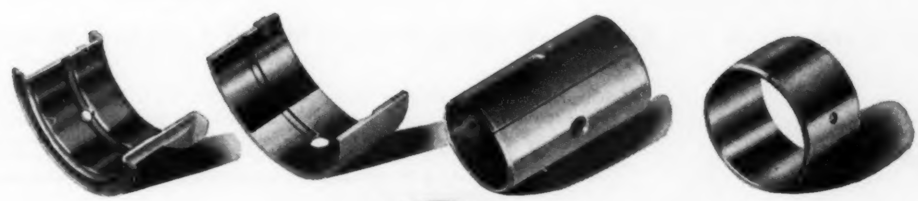


Bearings for industry



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RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

Circle 426 on page 19

CONTOUR-TRENTWELD

welded stainless pipe that's smoother, stronger

New Contour-Trentweld outperforms any other pipe, welded or not. Here's why: *Contour-Welding* is an entirely unique method of producing pipe and tubing. It puts gravity to work to pull down the molten weld metal until it exactly conforms to the contour of the pipe. Result: A smooth pipe or tube free of undercut or bead.

What's more, the *Contour-Weld* process *starts* with uniformly rolled stainless strip, which insures constant wall thickness throughout the pipe.

But the only way you can fully appreciate the advantages of new *Contour-Trentweld* is to try it. We think you'll agree, ***it can't be beat by any other pipe, welded or not.***

Why Trent's Exclusive Contour-Welding Process Means Smoother Welds . . .

Normally, in producing welded pipe, the weld is made at the top. But gravity plays a nasty trick. It tugs at the fluid metal in the weld zone, pulling it down toward the middle of the pipe. The result, particularly in the heavier gages, is a perceptible bulge where it hurts the most – right on the I.D. surface. If you try to get rid of the bulge – at fair cost – the metal is undercut – and corrosion and erosion start there.

But Trent put a stop to that – simply by going into partnership with gravity. With their exclusive *Contour-Welding* process, they weld at the bottom – and gravity works for them. For then, the bulge is in the opposite direction – blending in perfectly with the contour of the pipe itself.

CONTOUR TRENTWELD

Stainless and High Alloy Welded Tubing

TRENT TUBE COMPANY, GENERAL SALES OFFICES, EAST TROY, WISCONSIN (Subsidiary of Crucible Steel Company of America)

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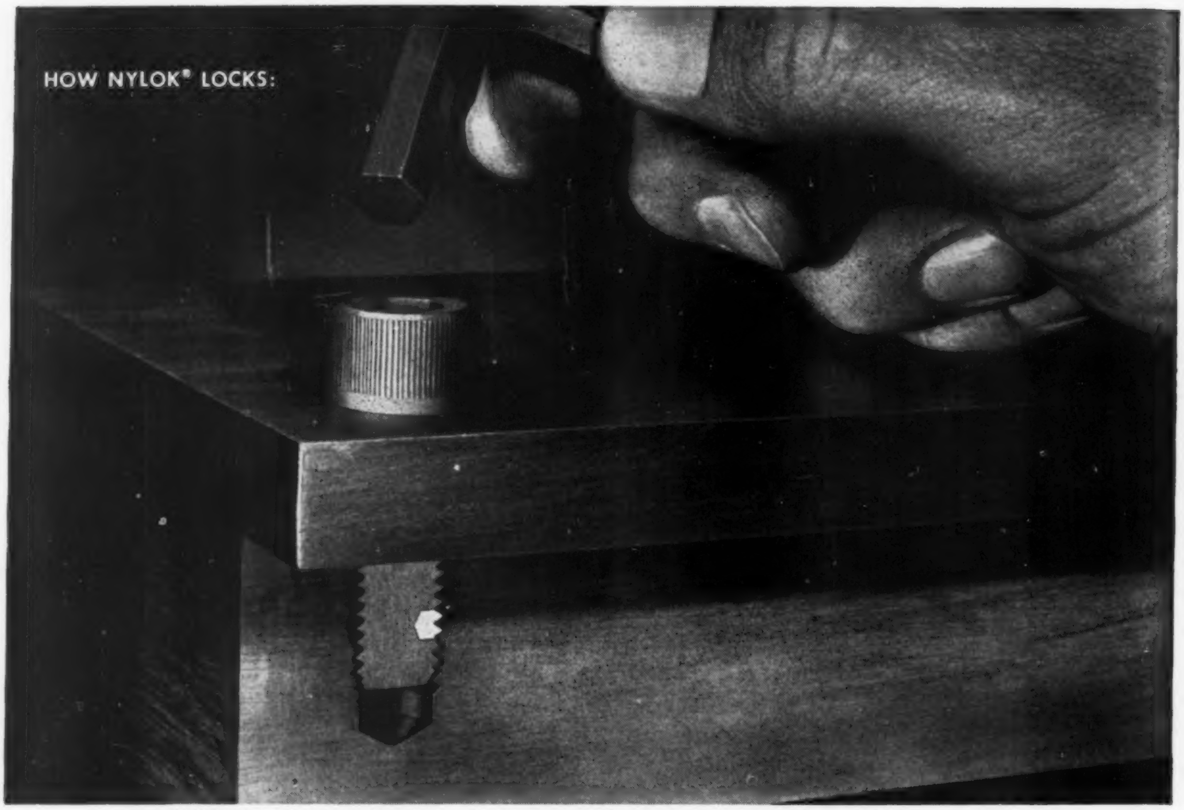


LOCKED! The tough, resilient nylon pellet keys itself into the mating threads. It forces threads together, and locks the screw securely.

NEW—a complete line of self-locking UNBRAKO socket screw products that won't work loose

They simplify design and save production time

UNBRAKO socket screws are now available embodying the Nylok* self-locking principle. Nylok provides a truly practical new solution to the problem of making screws self-locking.

You save production time when you build products with self-locking UNBRAKOS. And you get greater simplicity in design with less bulk and weight. The number of parts you must assemble to achieve full locking action is reduced to the absolute minimum. Lockwashers under screw heads are no longer necessary. Costly wiring of cross drilled heads is eliminated. So are cotter pins and complex multiple set screw installations.

Self-Locking UNBRAKOS are completely reusable. They have uniform locking and installation torques—with no galling or seizing on mating threads. They successfully withstand temperatures from —70° to 250°F. And, on properly seated screws, the pellet acts as a liquid seal.

Self-locking UNBRAKO socket screws come in a complete range of standard sizes and materials. See your authorized industrial distributor. Technical data and specifications are detailed in Bulletin 2193. Write us for your copy today. Unbrako Socket Screw Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

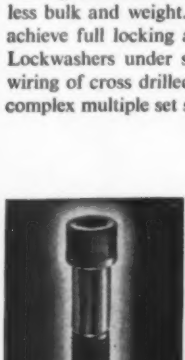
*T.M. Reg. U.S. Pat. Off., The Nylok Corporation

UNBRAKO SOCKET SCREW DIVISION

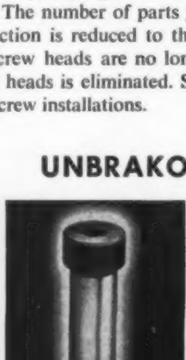
STANDARD PRESSED STEEL CO.

SPS

JENKINTOWN PENNSYLVANIA



Socket head cap screws. Standard sizes #6 to 1 in.

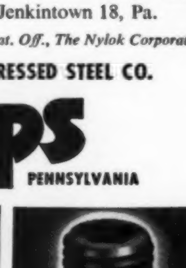


Socket shoulder screws. Standard sizes ¼ to ¾ in.

Flat head socket screws. Standard sizes #6 to ¾ in.

Button head socket screws. #6 to ⅝ in.

Socket pressure plugs. Standard sizes 1/16 to 1¼ in.



Socket set screws. All standard point types. #6 to 1 in.

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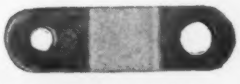
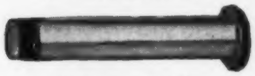
"Stress raisers" eliminated by Link-Belt LXS chain design

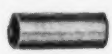
LXS "FULL-ROUND" DESIGN



"Full-round" pitch holes . . . no sharp corners



"Full-round" pin



"Full-round" bushing

"FULL-ROUND" DESIGN eliminates stress concentration points. Heat treatment of all parts adds even greater strength and extra wear life to selected steels. Accurate control of these processes avoids brittleness, poor wear values and low tensile strengths . . . and assures uniformity.

Large pins, bushings mean ample live bearing area for long life

For long life under severe conveyor and drive conditions, Link-Belt LXS chain provides extra strength, increased wear resistance and wider application flexibility. This fabricated steel roller chain incorporates many advanced design and manufacturing refinements, resulting in superior ruggedness and accuracy.

Eliminate weak points

"Full-round" design does away with stress concentration points most frequently subject to failure . . . provides maximum live bearing area between pin, bushing and sidebars. As a result, stress is distributed evenly, increasing chain life.

Pins and bushings are accurately sized for controlled press fit, preventing rotation in sidebars. Made from selected bar steel, sidebars are carefully machined for proper pitch hole size and for maintaining firm, tight press fit of pins and bushings. This assures close control of pitch and proper chain length after assembly.

Hardening extends life

Another Link-Belt long-life extra is the controlled hardening of selected steels used in the manufacture of LXS chain. Pins, for example, are made from a tough steel, specially treated for high strength in shear and for maximum wear value. Bushings are properly hardened to shrug off shock and resist wear.

Rollers are accurately machined to assure proper operating clearances and free-rolling action. Controlled hardening gives them the necessary resiliency and durability.

LXS especially popular for exposed drives, high impacts

Link-Belt LXS chain is the long-life answer for exposed drives, abrasive and high-impact conditions. Its large, live bearing area reduces cutting action of abrasives because load is spread over a broad area.

LXS chain provides extra strength, wear-life for heavy-duty conveying

Link-Belt LXS chain has real stamina—as shown in this conveyor application for handling 1000-pound, 40-foot lengths of steel pipe. Thanks to accuracy of pitch and attachment spacing, plus close matching of multiple strands, LXS has the added strength and wear life for the extra-long conveyors so popular in today's move to mechanization.

For help with any chain problem call your nearby Link-Belt office. Send for 342-page catalog 950 covering the complete line of standard Link-Belt products for conveying and power transmission.

LINK-BELT

THE SYMBOL OF QUALITY LB LINK-BELT

CHAINS AND SPROCKETS

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,280

More Strength, Less Weight. This lift truck, in use at Baltimore Concrete Plant Corporation, and manufactured by Gerlinger Carrier Company, Dallas, Oregon, is the largest standard-line lift truck on pneumatic tires in the world. USS "T-1" Steel reduced the width and thickness of the forks on this truck. In addition, this extremely tough constructional alloy steel eliminated the need for shipping the forks 75 miles for heat treatment, which was required with the alloy steel previously used.

HOW IT CAN HELP YOU

USS "T-1" Steel, with its high minimum yield strength of 90,000 psi and its minimum tensile strength of 105,000 psi, can help you design or build lighter-weight equipment that will last longer. Its unusual toughness can help you design or build equipment capable of taking severe impact and abuse at sub-zero temperatures. Its excellent weldability can help you cut the cost of fabricating highly stressed parts, and reduce repair and maintenance expense. Its good creep rupture strength can help you put more durability in equipment that operates at temperatures as high as 900 degrees F.

Somewhere in your operation, versatile USS "T-1" Steel can help you. Write, wire, or phone United States Steel, Pittsburgh 30, Pa.

UNITED STATES STEEL CORPORATION, PITTSBURGH • COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
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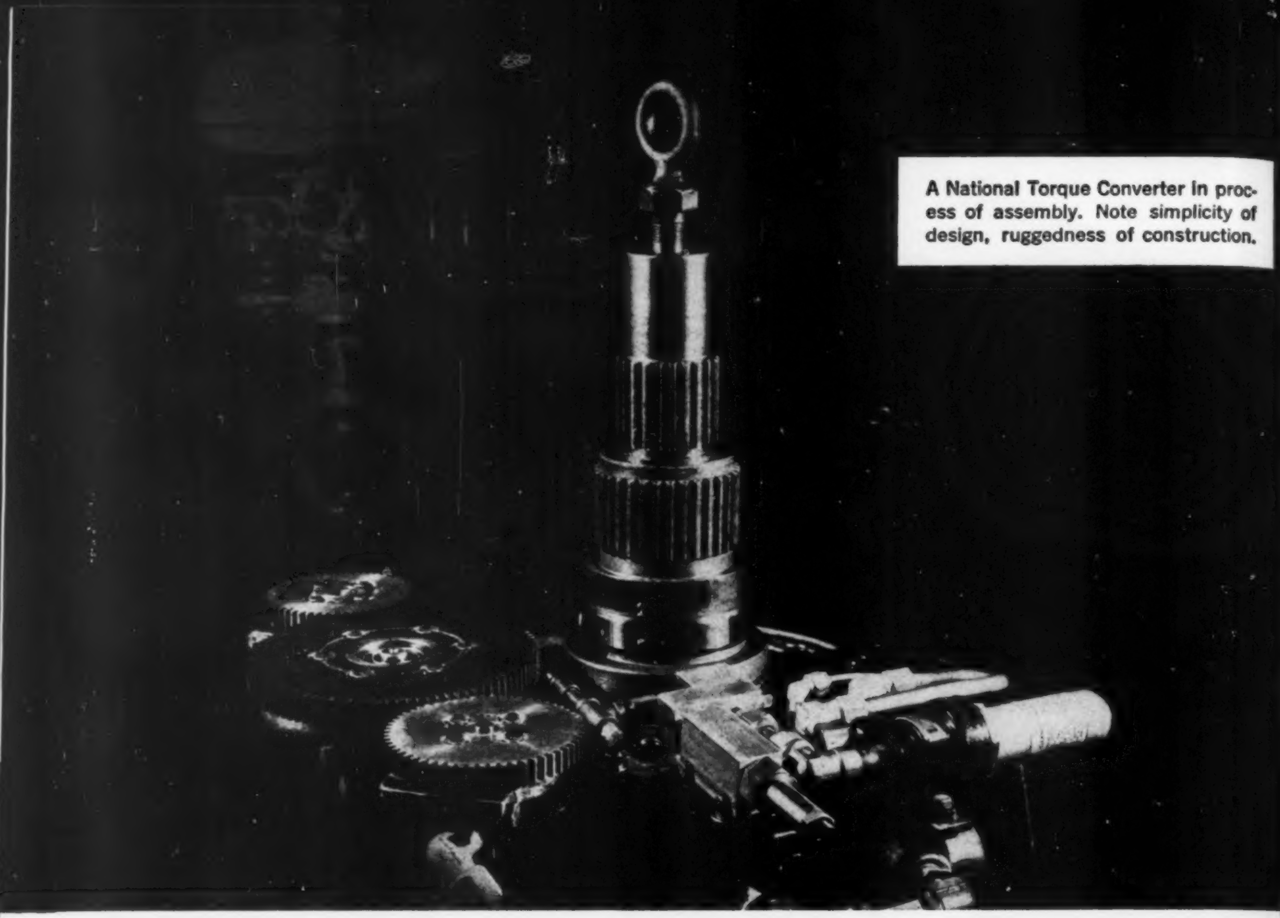
USS "T-1" CONSTRUCTIONAL ALLOY STEEL

See The United States Steel Hour. It's a full-hour TV program presented every other week by United States Steel. Consult your local newspaper for time and station.

UNITED STATES STEEL



A National Torque Converter in process of assembly. Note simplicity of design, ruggedness of construction.

National Torque Converters are designed and built to fit your requirements

The simple, rugged design of National Torque Converters gives you many outstanding features such as these:

Easy installation of torque converter. Long equipment service life. Minimum maintenance of equipment and torque converter, even in toughest industrial service.

With a National Torque Converter, the engine or motor attains optimum speed quickly . . . delivers full horsepower to the job smoothly and continuously. Your equipment will do more work per unit per operator per day.

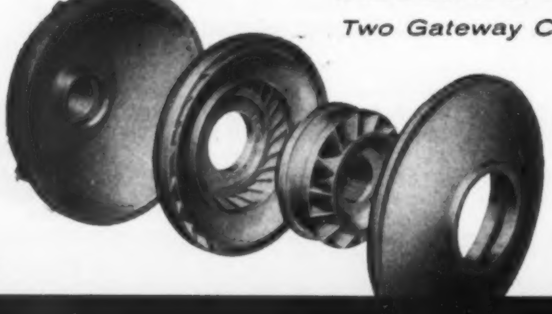
You have a choice of 6 basic hydraulic circuit sizes, each with a range of input ratings, permitting exact matching of torque converter to gasoline or diesel engines or electric motors of 100 to 1000 horsepower.

National engineers will gladly work with your designers to find the correct size and capacity of National Torque Converter for the specific power–speed characteristics of your equipment. Why not call on them, and get the benefit of their experience? Write The National Supply Company, Two Gateway Center, Pittsburgh 22, Pa. Ask for a copy of Bulletin No. 468.

THE NATIONAL SUPPLY COMPANY

INDUSTRIAL PRODUCTS DIVISION

Two Gateway Center, Pittsburgh 22, Pa.



Pace-setters in the progress of industrial power transmission

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(Advertisement)

CORNING GLASS BULLETIN

FOR PRODUCT DESIGNERS

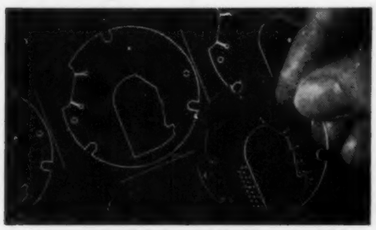
Etchings to excite exigent engineers

Next time someone says, "Make it small and accurate," reach for your file on *photosensitive glass*.

Using a process called "chemical machining," photosensitive glass now yields intricate and accurate components for both electrical and mechanical applications.

Starting with a Corning special glass, chemical machining makes it possible to achieve an intricacy never before thought possible. And it's all done *without* the need for costly grinding, drilling, cutting or engraving.

Let's take a look at some chemical machining in practice, a good example being this wire brush holder for a tiny airborne digital converter.



Made of glass by a combination of photo, heat and etch processes is this precision brush holder for a digital converter. In background are holders that have been exposed and developed but not yet etched.

As originally designed, this converter had 0.0065″ single wire brush contacts. Brush holders were of a glass fiber reinforced laminate. But, the smallest holes that could be drilled in this laminated material were 0.015″ in diameter. Result? Loose-fitting wires.

Turning to the miniaturization and precision offered by photosensitive glass, designers came up with a brush holder with *rectangular* holes, 0.0075″ x 0.015″.

Two wires (each 0.0065″) are inserted side by side in each hole. Holes are etched through the glass and have a conical cross section. The lip of this cross section serves as a reference point about which the free ends of the brush cantilever.

Spacing of the slots is held to a tolerance of 0.001″ over 1½″, making it possible to position the double brush contacts with close tolerances.

Etched glass also plays a role in assembly, with an alignment plate used to locate the free ends of the brush while fixed ends are cemented.

Behind this *accuracy-by-acid* is some quite ingenious exploiting of differential rates of etching glass. And there's also some interesting use of collimated ultraviolet light and heat.

You can learn a great deal more about photosensitive glass (including other uses) by writing for "Chemical Machining Photosensitive Glass," a reprint of an article that ran in *Materials and Methods*. Free with the coupon.

Viscosity, visibility and versatility

From the production lines of the Precision Scientific Company of Chicago comes this Transformer Oil Oxidation Test Apparatus.

This bit of precise plumbing is a second cousin to another Precision product, the Model "S" Kinematic Viscosity Bath.

Used profusely in both is PYREX brand glass No. 7740. First, there are PYREX brand jars (12″ x 18″) forming the main chambers of the test apparatus. Then you'll find an almost bewildering array of tubes and tubing, some of it quite intricate in shape. And there are also Erlenmeyer flasks and glass umbrellas.

Behind Precision's choice of glass is the need for visibility, plus *accuracy and precision*.

PYREX brand glass No. 7740 handles all these requirements admirably. It's known as the "balanced glass,"—balanced for chemical stability, heat shock and physical knocks.

No. 7740 demonstrates a remarkable reluctance to mix with, or be affected by, what you put *in* or *around* it. Among the usually destructive forces that bother it not at all are most acids and alkalies, as well as steam.

This *not adding to or detracting from* is one reason why No. 7740 is the favorite among those who must protect delicate flavors. That's why, for example, you'll find this glass in coffee makers, both commercial and household varieties.

And PYREX No. 7740 stands up to physical knocks. It takes thermal shocks in its stride, too, having a linear coefficient of expansion of 32.5×10^{-7} between 0° and 300° C.

A clear glass, it's available in economical quantities as blown or pressed ware, and in plates, panels, tubing and rod.

Even one-piece molding of fancy shapes has been done with this most popular of all glasses made by Corning.

Can some particularly knotty problem of yours find its answer in this or some other glass by Corning? Good way to start finding out is with our Bulletin B-83, "Properties of Selected Commercial Glassware." It details characteristics of many of the glasses sold under the PYREX, CORNING and VYCOR trademarks.

This basic reference volume is yours for the asking. You can get one quickly by using the coupon.

Still available . . .

"Glass and You," a profusely illustrated volume showing how many businesses and industries use glass profitably.

And there's Bulletin B-84, "Manufacture and Design of Commercial Glassware," a brief summary of design considerations in making glass by various methods; also data on sealing and assembling glass to metal.

Plus an invitation to consult with us via the written word, phone, or wire, on utilization and availability of *glass* as a basic material of design and construction.

With 105 years of experience in glass technology behind us, and with the formulas for some 65,000-odd different glasses on tap, we've acquired quite a bit of useful know-how.

You can make use of it at your convenience. And, if you're in the area, be sure to stop by at The Corning Glass Center. Here you will find both the oldest and the newest uses for glass. We would be glad to send you a preview of what may be seen. Check the coupon.

Corning means research in Glass

CORNING GLASS WORKS, 52-12 Crystal Street, Corning, N. Y.

Please send me the following material: Reprint, "Chemical Machining Photosensitive Glass" ☐; Bulletin B-83, "Properties of Selected Commercial Glassware" ☐; Illustrated Booklet, "Glass and You" ☐; Bulletin B-84, "Manufacture and Design of Commercial Glassware" ☐; "Your Tour of The Corning Glass Center" ☐.

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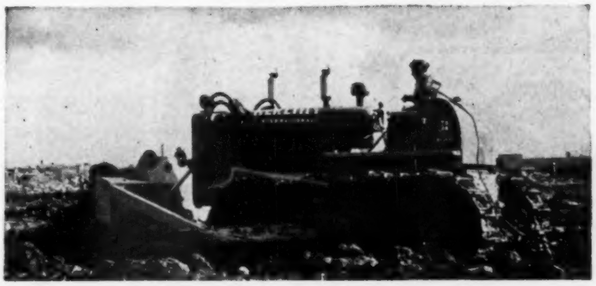

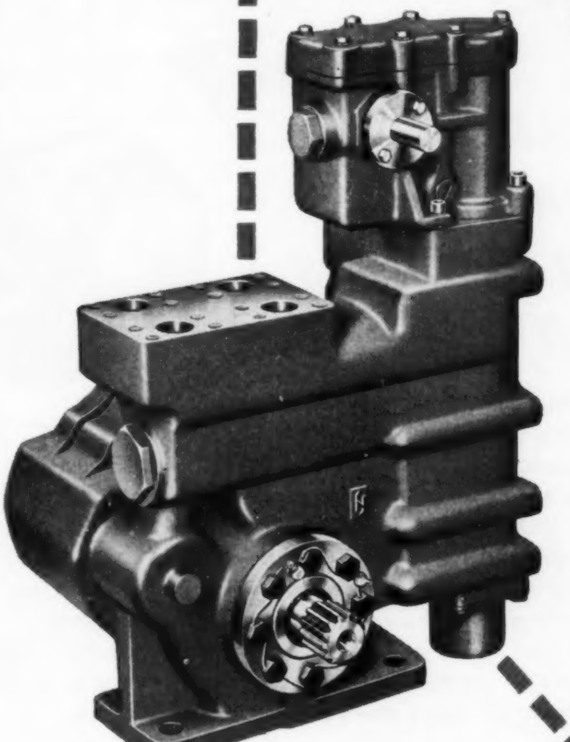

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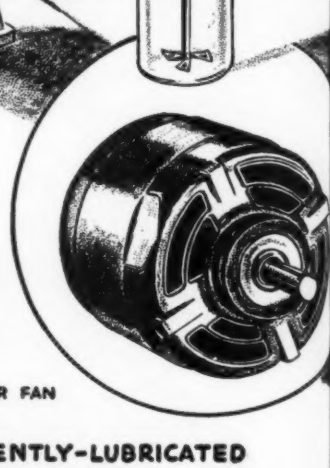
Circle 434 on page 19

DESIGN SOLUTIONS with G-E



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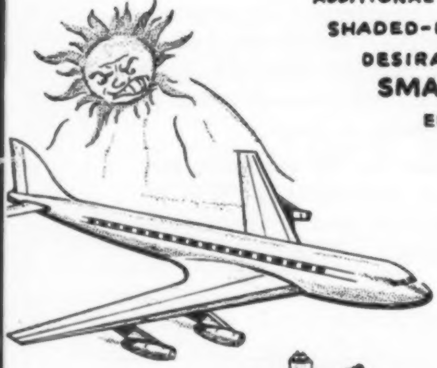
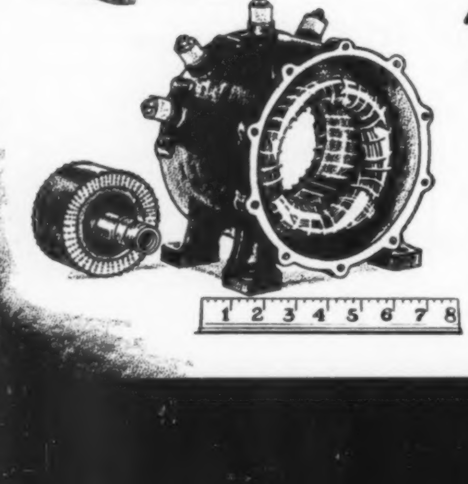


AIRLINERS COOLED BY HERMETIC MOTOR PARTS LESS THAN 6½ INCHES IN DIAMETER--25 HP DELIVERED CONTINUOUSLY AT 23,500 RPM.



HERMETIC MOTOR PARTS WITH **DIAMETER OF ONLY 6 5/16 INCHES WEIGH ONLY 18 POUNDS**--YET DELIVER 25 HP CONTINUOUSLY AT A SPEED OF 23,500 RPM!

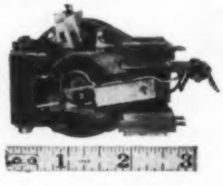
DESIGNED TO POWER AN AIRBORNE COMPRESSOR, THESE PARTS-STATOR, ROTOR AND SHELL-ARE COOLED BY FREON CIRCULATING THROUGH THE SEALED PARTS. THE COMPACT TWO-POLE, 400-CYCLE CONSTRUCTION MAKES POSSIBLE A CONTINUOUS 25 HP RATING.

Circle 435 on page 19

Haunted by a Horse?

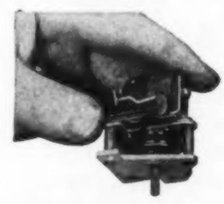
Got a problem in power capsulation, weight and size reduction, design diminution? — so horsepower is giving you the horrors? More than 500 types and sizes of MPB's* such as these  BALL BEARINGS ACTUAL SIZE can help to make your horsepower headaches smaller, lighter and easier.

MPB's* at work



An MPB radial bearing translates rotary to lineal motion in this fire control relay. It increases sensitivity and dependability while reducing wear and withstanding severe shock loads.

Miniature gear differential designed to permit coaxial shaft mounting on one end of housing. Seven MPB flanged radial bearings and two superlight radial bearings are used in each unit.



Indexing mechanism using MPB miniature bearing as an index pawl operated by the miniature solenoid at top. Friction clutch drives index disk, allowing overtravel when rotator is suddenly stopped.

***MINIATURE PRECISION BEARINGS, INC.**

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Using

DU PONT ELASTOMERS

NEOPRENE · HYPALON®

in Design

Coatings of HYPALON® add beauty and durability to a variety of products

Du Pont's new synthetic rubber, HYPALON, can now be applied as a protective coating on rubber, metal, wood or fabrics. It can be applied by spraying, brushing or spread coating. The development of these coatings, both clear and colored, has opened new avenues of product design in a wide range of applications. Here are the advantages such coatings offer:

HYPALON is unaffected by ozone. It has unusual resistance to hardening at elevated temperatures (250°-350°F.). It is unique in its resistance to weathering and oxidizing chemicals. And, in addition to the protective benefits of HYPALON coatings, an unlimited range of stable colors is available to add beautiful and functional color to your products.

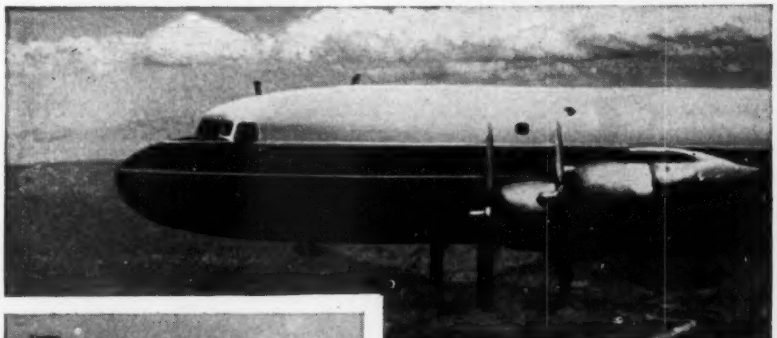
Applications for HYPALON coatings include tank linings, footwear, tarpaulins, camera bellows, hose, belts and automotive and sporting equipment. For other uses see the photograph below.

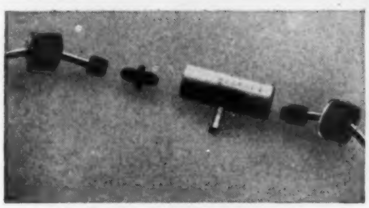
How can coatings of HYPALON fit into your design problems? Mail the coupon for more detailed information about your specific problem.

These products feature attractive protective coatings of HYPALON: a piece of corrugated rubber mat (left foreground); a coil of electrical wire, and a child's overshoe on the mat; rubber extrusions for automobile windshield frame and trunk weatherstripping (center foreground); door weatherstripping (right foreground); slab of urethane foam (left rear); basketball (right rear).

Circle 437 on page 19

NEOPRENE SEALS safeguard fuel line connections in the Douglas DC-7





SEAL READY FOR ASSEMBLY

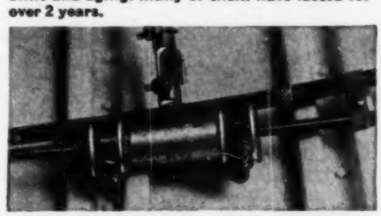
Safety of passengers is uppermost in the minds of Douglas Aircraft designers—even down to as small an item as the rubber sleeve on a fuel line connector. Douglas uses the best metal connectors to join its fuel lines, but as an additional safety factor the company fits a vapor-tight sleeve seal over each joint which is vented by tubing to the ship's exterior to prevent any possible accumulation of highly flammable gasoline vapors within the fuselage.

Before switching to neoprene, Douglas had a problem with the seals. They required frequent replacement because ozone caused the rubber to crack. In fact, many of the rubber seals were rejected as unusable before installation because of ozone cracks which developed while the pre-assembled units were held in stock.

The installation of neoprene seals proved to be the answer to the problem. Neoprene was chosen because it resists ozone, gasoline, oil and aging. Many of the neoprene seals have been in service for over two years, reducing maintenance and replacement costs.

Perhaps your design problems can be solved by the use of Du Pont neoprene. We'd be glad to send you further information—property data and proven applications. If you have a specific problem, please let us know in the coupon.

NEOPRENE SEALS (in red) resist ozone, oil, gasoline and aging. Many of them have lasted for over 2 years.



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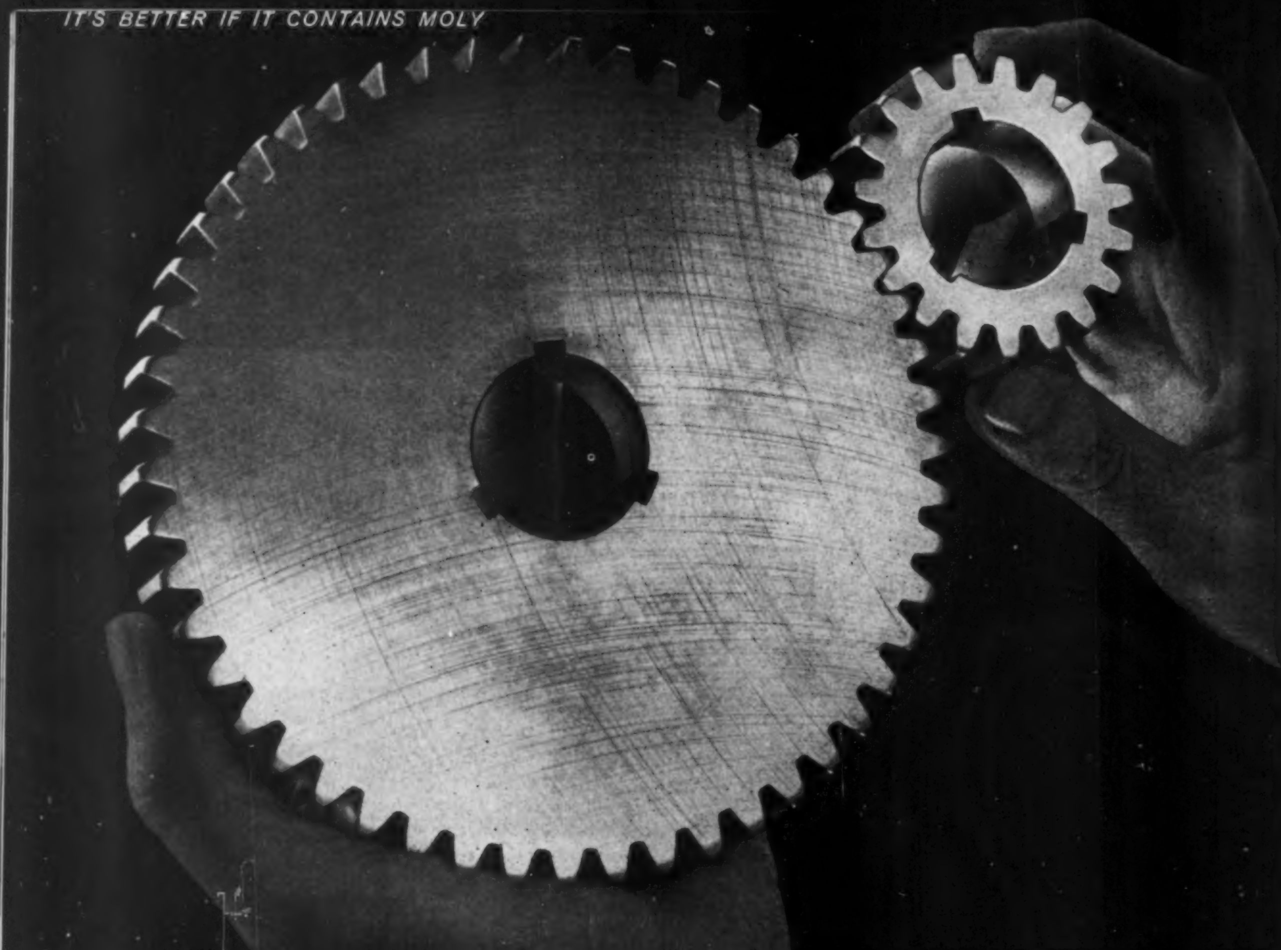


Up to 1% Moly in carburizing steels gives required hardenability economically

Why limit the use of molybdenum to the .15/.25% Mo and .20/.30% Mo contents of the traditional grades? For the contributions of moly do not stop there. Laboratory tests and production runs prove that as molybdenum contents increase up to 1%, hardness increases progressively. A wide range of case and core hardenabilities, therefore, can be obtained – economically, too.

Tests with a series of molybdenum-manganese steels show that these compositions give higher case hardness on a direct quench than other steels of comparable core hardenability. One extensively tested composition, for example, is 0.5% Mo – 0.5% Mn steel. It shows longer life, and is lower in cost than steels previously used. And it produces a higher case hardness with similar or less distortion. What's more, tool life and surface finish are equal or better. Good reasons why several companies have already adopted this grade for automotive gears and other critical applications.

If you use carburizing steels, see what a higher molybdenum content can do for you. Part of the story is contained in the technical article "New Carburizing Steels For Critical Gearing." For your copy, or other technical data, write Climax Molybdenum Co., Dept. 11, 500 Fifth Avenue, New York 36, N. Y.

CLIMAX MOLYBDENUM

Circle 438 on page 19

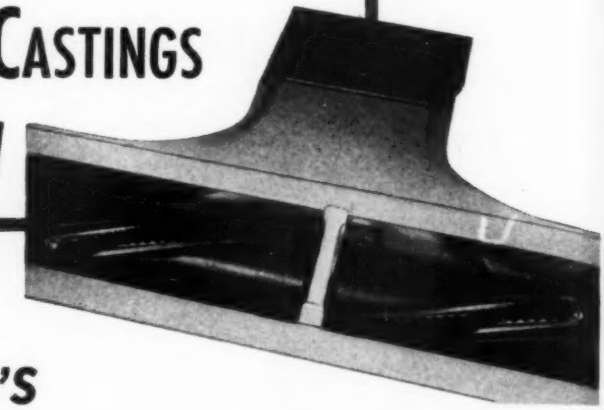
CLIMAX MOLYBDENUM

Use the Moly Key to better carburizing steels

- High case hardness
- Wide choice of hardenability
- Easy to heat treat
- Low distortion
- Good machinability
- Good wear resistance

Circle 439 on page 19

There's a Good Reason why ZINC Die Castings are so widely used



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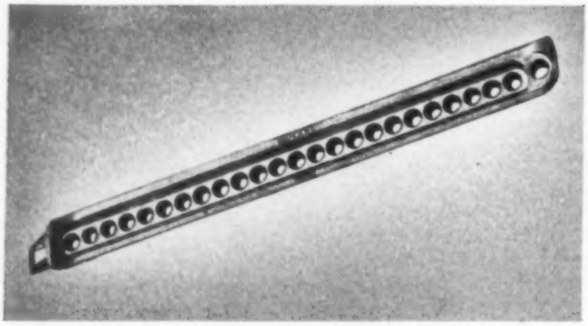
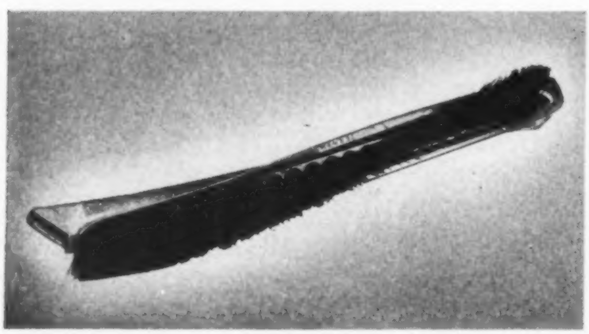




The straight die casting (at top) is put into production without any machining. The bristles are fastened in place and the forming operation twists the bar to the proper curvature for installation on the agitator.

Design engineers at The Hoover Company found that DUCTILITY provided the necessary answer to their problem of using ZINC Die Castings in the agitator of the upright electric vacuum cleaner.

Because of the helical contour of the brush, the metal back could not be die cast to the required shape since the anchoring holes for the bristles would not be parallel to the motion of the die. The problem was neatly solved by a die caster who knew how to use the exceptional qualities of ZINC Die Castings.

The brush backs were cast straight, the bristles anchored in the holes and the castings were then cold formed approximately 115° to give the necessary helical contour. Even with the extra forming operation, die casting proved to be the most economical method of production since no machining was necessary.

Ductility is just one of the many physical and mechanical advantages that make ZINC Die Castings so widely used by manufacturers who want the best product with lowest costs of parts and assemblies.

ZINC
FOR DIE CASTING ALLOYS

THE NEW JERSEY ZINC COMPANY *160 Front Street, New York 38, N. Y.*

The research was done and the Zamak die casting alloys were developed with

HORSE HEAD SPECIAL (99.99 + % Uniform Quality) ZINC

Circle 440 on page 19

MACHINE DESIGN
DECEMBER 27, 1956

A Design Machine?

PROMINENTLY featured in the November issue of *Fortune* is a proposed "design machine" which is offered as one of several ideas for accelerating research and engineering methods to match production speeds.

Pictured at the control console is an "engineer" who has just typed out a description of a part, which the machine has promptly revealed to him as a 3-D view on a screen.

There's only one snag in this hopeful picture. The machine has not really "designed" the part. That has obviously been done already, as evidenced by a pencil sketch which was the operator's guide in punching the machine's keys.

So the function of the machine is basically that of drafting—establishing exact dimensions for parts whose general configuration is already known. As an extension, this machine of the future would also control directly or through tapes the power tools to produce the part.

Such a device conceivably could be a useful aid in speeding-up engineering development, but let's not call it "design" or its operator an "engineer."

At the other end of the scale is a very different sort of activity, one which is engaging more and more engineers today but for which there are no foreseeable machine aids—organizing large engineering projects.

Mobilizing immense throngs of engineers and scientists for the design and development of huge, complex and hitherto unheard-of machines and systems offers challenging problems—organizational, technical and human.

H. F. Lanier's thought-provoking article beginning overleaf gives a glimpse of what's ahead for engineers in this area of endeavor. His picture of the inputs and outputs which the creative engineer's brain must process is all the evidence needed to dispel the notion that a true "design machine" will ever cause technological unemployment among engineers.

Colin Carmichael

EDITOR

Organizing for

Large Engineering Projects

By H. F. Lanier, *Project Engineer*
Aerophysics Departments
Goodyear Aircraft Corp.
Akron, Ohio

Organizing engineering for maximum results in minimum time is no small task. But when projects become huge and complex, the problems can grow to staggering proportions.

Such projects—current and contemplated—are demanding a new approach to engineering organization.

Here's an analysis of the problem and suggestions on how it can be solved. Although concerned primarily with large-scale engineering programs, this discussion may also provide helpful viewpoints for operations of any size.

ENGINEERING organization is undergoing a revolution. This has been brought about by the advent of new large projects, the shortage of engineers and a general increase in complexity of engineering problems. Perhaps the most action can be seen in the engineering of large systems such as the Air Defense System, various guided missiles, and color television.

A typical large engineering project employs a team of specialists who must work closely together and be supervised by one of their number. These teams, as defined here, include subprofessional engineering aids, but do not include such things as plant engineering, tool engineering, and similar functions. This distinction is, however, being modified in some companies.

In numbers these teams vary from 200 to 2000 men. But 4000 to 6000-man teams are foreseeable and undoubtedly will come to pass. There appears to be at least one effort that requires a 20,000-man team.

Need for Co-ordination

The problem of organizing such a team is in the broadest sense that of arranging and guiding a large number of diversified people so they all think productively on facets of a single problem without too much overlap and with complete coverage.

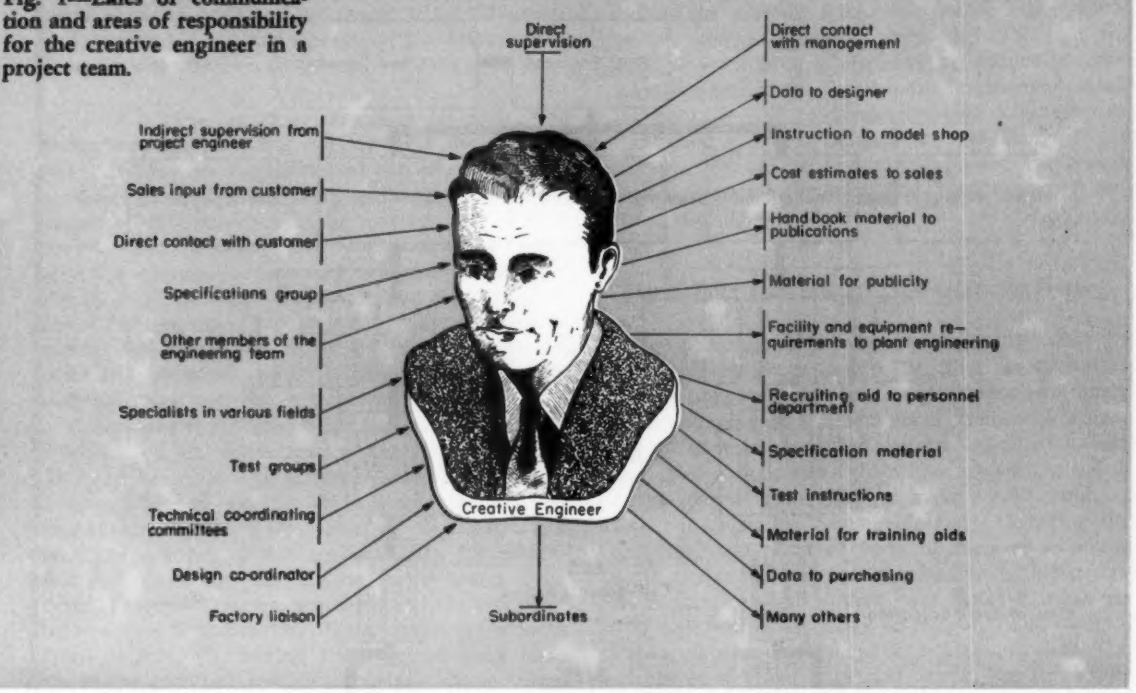
The basic unit of this team is the creative, specialized engineer. He must be free to invent, yet thoroughly bound to co-operative effort. He must communicate a picture of his end product to many people long before it is finished. The many and varied "inputs" and "outputs" he must contend with are depicted in Fig. 1.

Traditional Approach: The tradition of proper line organization doesn't fit this man, and it obviously is difficult to maintain a large number of such men in close harmony, and simultaneously get work done efficiently.

The problem can perhaps be best illustrated by considering the difficulties of trying to fit a number of creative people into the precise and orderly line organization shown in Fig. 2. Under this plan, all work is thoroughly organized and all assignments rigidly controlled. Each individual has a definite area to cover, definite data to work with, and a schedule to meet. He also has a boss who tells him what to do and subordinates whom he tells what to do. This organization once set up is soon limited to the creative output of a few men who lead. Any innovation is difficult to introduce because it requires detailed instruction at all levels.

Lines of Communication: Large problems must be broken down by someone into blocks that fit together. Then these blocks must be broken down

Fig. 1—Lines of communication and areas of responsibility for the creative engineer in a project team.



further until the tasks are of one-man size. Since each man is a specialist in a different area, his block is an apple in a basket of eggs to his view. He can only carry out his own assignment to the satisfaction of his boss.

To illustrate this, suppose a simple plot must be developed into a TV play. To speed the process, a chief writer divides the plot among four assistants as follows: (1) A miner finds uranium (2) but is shot by his partner (3) who then can't find his way (4) out of the woods. Each assistant must write so many minutes of play around his phrase. Then all are assembled into the final production.

The complication is obvious and the need for coordination very great. When this assignment is carried on to the next echelon, where each man gets one word to elaborate on, the difficulties are ridiculous. Yet examine a realistic case. A multimillion dollar project is started by a work statement as follows:

> Develop, design, and test a guided missile to fly at *w* altitude for *x* miles, carrying *y* pounds of warhead. Include all ground support equipment, spares, test equipment, special tools, manuals, training aids, etc., that may be required. Provide drawings, tools and facilities for *z* units and actually manufacture certain samples. Provide the whole set simultaneously and in a short time.

It may seem absurd but hundreds of people in this country were given assignments such as: Provide test equipment for the missile specified in this paragraph. One word out of a novel to expand upon! Obviously, those who succeeded didn't take their assignment at face value. They effectively redefined their assignment in some fashion to face an otherwise impossible problem. The major step is somehow to break down the long lines of communication.

Methods of Approach

In defense of management which passed out such assignments, the organizations in question had a habit of succeeding on large problems. Many perturbations were experienced apparently because two important factors were misjudged: (1) time per development cycle and (2) number of research problems and development tasks which must be integrated into one item.

Time Factor: Established industries, such as transportation, have problems in all areas, but usually operate on a long time cycle—perhaps twenty-five years for introduction of anything really different in the way of an overall system. The number of tasks and problems may be several thousand. It hasn't been possible to observe the organizational problems clearly in this area because of the time span involved. A mod-

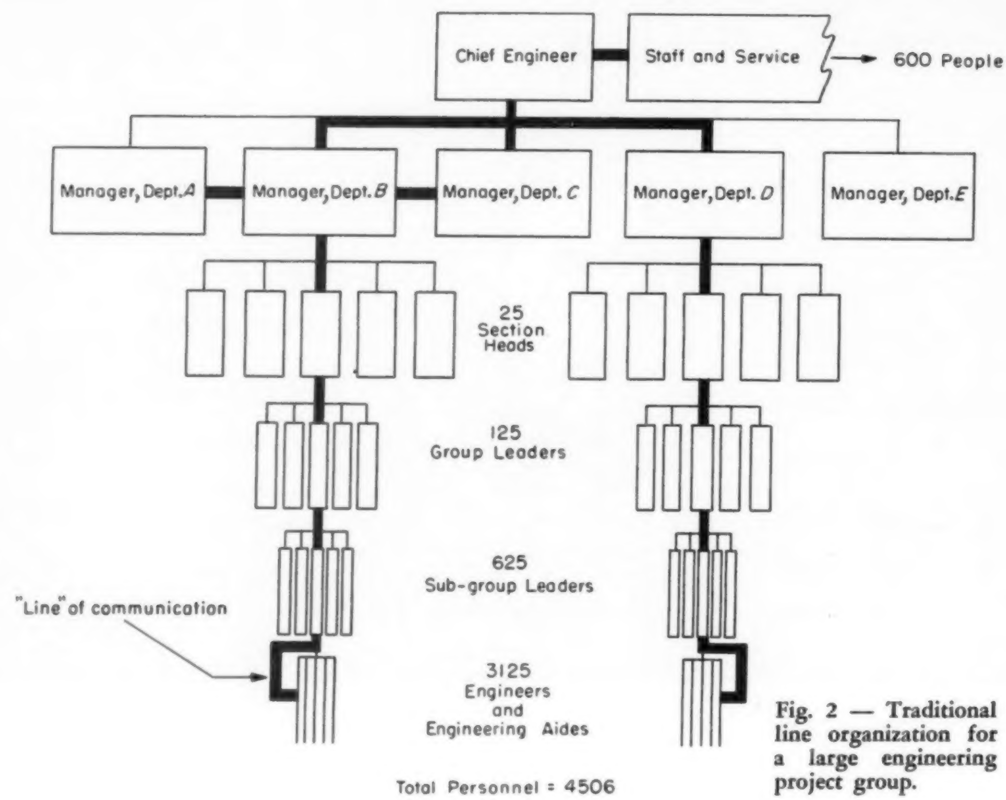


Fig. 2 — Traditional line organization for a large engineering project group.

ern military project may have approximately an equivalent number of tasks condensed into five years.

As a result, military large systems which have a tendency to be hurried to the limit of reason offer a useful laboratory for examining problems in the organization area. The hurry provides a cause and effect cycle short enough to let observers use the results of one project to improve the next. Furthermore, the problems are exaggerated and can readily be seen.

The usual solution was to allow a great deal of "co-ordination" and "liaison" to be handled informally. Effectively, supervisors unleashed their men and gave the program general direction but let detailed instructions be formulated after the fact. The loose method has been reasonably successful. The next obvious step is to attempt to systematize the process. Some new engineering disciplines seem called for and it would be well to train the required people by direct methods to facilitate rapid formation of new teams.

Of course, the organization must be assembled mostly from people of recognizable types. It is possible to develop some new specialties and otherwise modify people in time, but each such operation involves a considerable effort and cannot be entered into lightly, especially since wrong action could head the individuals concerned down a blind alley.

For this reason and others, most of the new organizations have been entered gingerly. Interim arrangements are common. However, as with most problems, the few wholehearted attacks have been most successful.

Application of Interim Arrangement: One outstanding example of the interim type is the National Television Standards Committee in its attack on color TV problems. Here, a system needed developing. Yet in no one company was there enough talent, capacity, salesmanship, information, etc., to do the job. The number and diversity of problems were not only beyond any one man's capacity to understand and tie together, they were beyond any one company's capacity.

In this case thirty companies combined forces to specify the color television system in detail, check their theories, assure themselves that all necessary apparatus was practical, and sell the whole thing to the government and the nation. The process used was a committee action wherein individuals were assigned areas to report on and all conclusions were presented through a chain of command, eventually being agreed to by all concerned.

Although ponderous in layout, this scheme was

spectacularly successful. The process superficially resembles a diplomatic conference in technique; yet it actually produced the design of an advanced and acceptable system where normal engineering development processes did not.

Effect of Project Size: On a small scale, the same technique is being applied to projects of all sizes. Where no one individual can encompass the complete understanding required to make technical decisions, a committee is formed to discuss and recommend. This has one real drawback: Usually the committee members are also line supervisors and hence can meet only for a fraction of the time required for efficient system development. In other words, actual development by committee is employed most effectively on an occasional relatively huge problem.

When large systems problems are the prime business of an organization, then a permanent fix must be made. Here the solution seems to be a committee of project or systems engineers—individuals trained to be jacks of all trades, and who are relieved of line responsibility for administering operating sections but who spend their time (1) developing systems as such, (2) receiving information from labs and tests, and requirements from outside, (3) having the required work done elsewhere and (4) co-ordinating the whole thing.

The project engineer is a feature as old as engineering. Groups of project engineers working in team effort under a project management is a little new.

The project-line combination organization has existed in various forms for some time, usually as a special purpose, temporary thing. Now enough work of the large system nature is under way to warrant the formation of permanent establishments geared to development of large systems. Continued existence of such an operation will permit growth of the specialized people required to make operation smooth and acceptance of new tasks routine.

Two-Dimensional Organization

Several companies are experimenting with the arrangement illustrated in Fig. 3. Here specialized creative engineering groups are given a two-dimensional supervision. A line supervisor heads a number of groups of related technical skill and training, and a task supervisor heads an array of diverse groups employed on a particular task. A line supervisor is responsible for (1) assembling and training a stable body of men of a certain skill, (2) organizing facilities and assigning groups as required to accomplish its appointed tasks and (3) assuring the quality of output. The task engineer is responsible for (1) fitting together all facets of a broad task, (2) arranging for accomplishment of subtasks by line groups, and (3) providing and fostering the necessary communications and direction to keep all working to the same aim and the right aim.

In addition, the manager of all task engineers

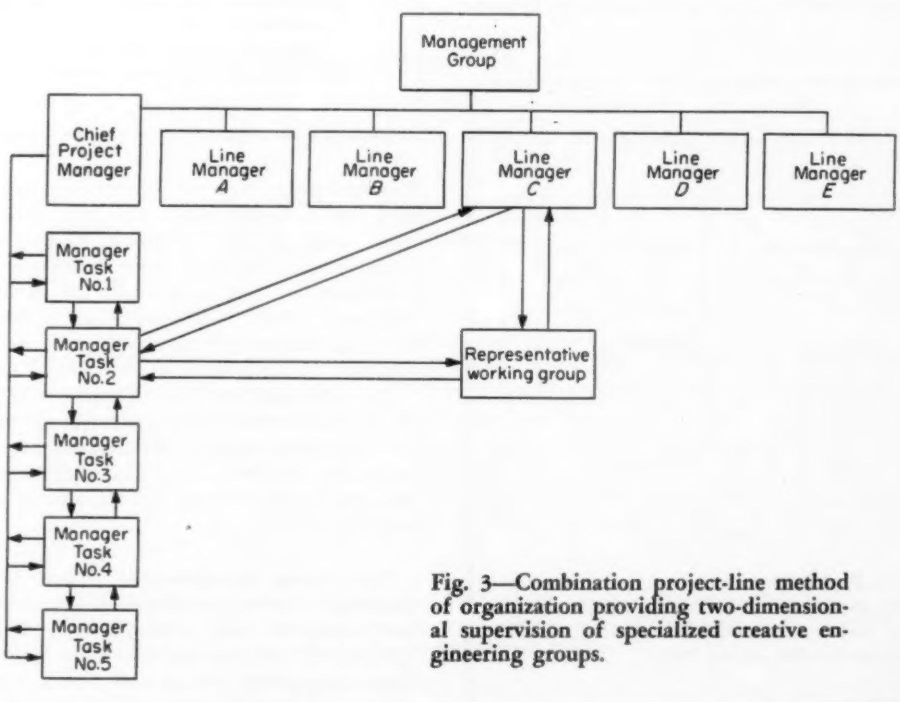


Fig. 3—Combination project-line method of organization providing two-dimensional supervision of specialized creative engineering groups.

has the responsibility for developing the technique of task engineering and training a body of task engineers to work together.

Personnel Relationships: As one would expect, to make this approach work requires a great deal of effort. The personnel concerned must be, to some extent, retrained and fitted into the pattern. Successful efforts of this type have been in process for two years or more and still require a constant training activity.

The relationships between supervision and subordinate, and group with group, are obviously complicated by this arrangement. Actually, the formal arrangements are complicated to match more nearly the actual, informal arrangements. Still, it isn't obvious to everyone that this is so and much discussion is required to reach amicable understanding.

Need for Specialization: The size of such organizations now in existence varies from about five specialized departments with five distinct tasks to twelve departments with twelve tasks. It seems to follow that, as the overall size grows, the number of recognized separate specialities increases. For example, a reliability function is recognized separately in many companies. This is brought about by the need for near perfect performance in systems at a time when very few or only one such are in existence. Clearly one can't afford to discard the first few defective units off an assembly line when the units cost a million dollars each.

One interesting function of a reliability group is to predict the best moment to fire a missile. Fig. 4 is an example of a probability of success curve. The probability of 0.7-hour successful flight is plotted against time, with critical points such as shipment noted. The trick is to fire as the probability nears a peak and before wear-out sets in. Such a function for smaller operations consists of a moment's decision by the boss, based on his knowledge of the situation. Here a separate group of people requires inputs, training and co-ordination.

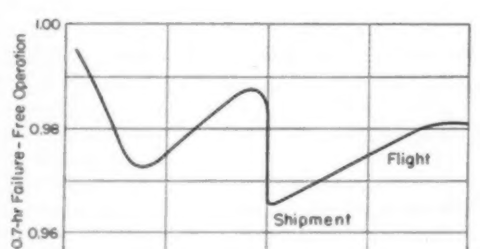


Fig. 4—Probability of success curve for predicting the best time to fire a missile. Probability values are based on frequency of failure of equipment during test.

Investment in the Future: Another facet of large systems is the great investment prior to the first real performance results. This forces a great resistance to innovation and yet a large system is likely to demand much innovation. The solution here is a series of partial and complete simulations of the eventual use, where test organizations do carefully engineered tests of sample, incomplete, and "breadboard" articles.

Again, testing of a product as it progresses is standard practice in all industries. The difference here lies in magnitude. The test must in many cases never be quite realistic. One can't test the actual consequences of color television or the effectiveness of a weapon until the development is long since over. This requires the formation of test organizations who are forever extrapolating toward tests they can't quite actually carry out.

The test engineer has in many ways a harder job than the man developing the article. In the case of guided missiles, the test engineer is rapidly becoming the key man. He has the problem of determining if a device will work for sure without working it.

Organizing Large Engineering Projects

Problems

1. Complex lines of communication that must span various scientific disciplines and organizational barriers.
2. Large investment prior to first realistic test.
3. Difficult morale and motivation problems in technical personnel.

Recommended Solutions

1. Recognize and formalize across-lines co-ordination.
2. Train specialists in project direction and co-ordination.
3. Train the whole organization in a philosophy of large-system engineering.
4. Establish an appropriate set of specialized engineering groups.
5. Mechanize routine paper work.
6. Provide the best facilities possible.

New Group Assignments: These are but two examples of the specialized organizations coming into existence. Fig. 5 shows some more. Above the line of main stream effort are the more traditional specialized groups now common to most industry. Below the line are many of the newer

groups becoming separate and performing functions that require co-ordination with project and line managers.

The specialized group opens the way to accomplishment not otherwise possible. But it further complicates the managerial problem and tends to force the development of specialists in project co-ordination.

Personnel Problems and Solutions

All of these tendencies are very upsetting to the well-trained engineer, accustomed to individual work. When transplanted into a large system organization, he will find himself directed to disclose data before it is finished, change his direction for "political" considerations, compromise perfection of his product for the benefit of the whole, and otherwise act like an irresponsible cog in the wheel.

Morale Problem: Much of his concern can be eliminated or reduced by training and a clear-cut exposition of the problems and proposed solution. However, any way you look at it, as the organization grows, many highly skilled, inventive men are placed in a position of reduced control over the direction and planning of their own work. The morale problem therein is reflected in the general unhappiness of engineers as revealed in a recent study.

The solution to this problem is being tackled in two ways. First, engineers are being grown in the atmosphere of large system projects and hence satisfied with them. Second, physical facilities are being improved. The latter method provides a working environment that is both physical evidence of stature in the company and an efficient place to do creative work, thereby in some measure compensating for the loss due to increased size.

Departmental Conflicts: Another problem is underlined by a recent experience of a large industrial concern. This company found it had a sort of cold war raging between its engineering division

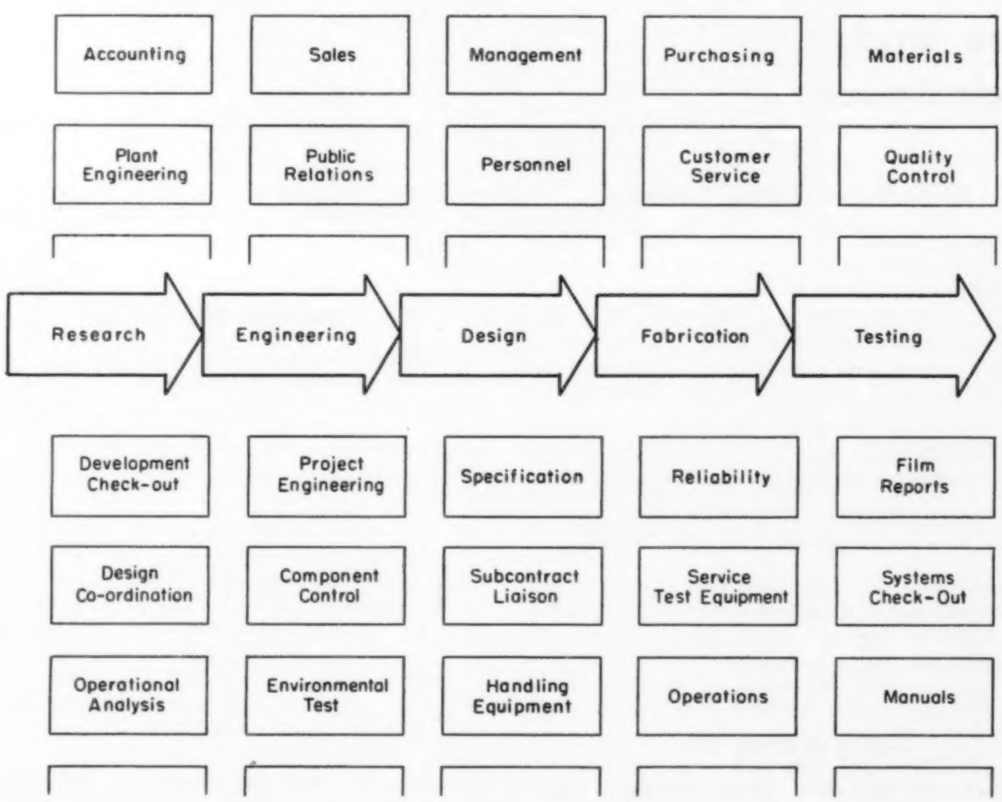


Fig. 5—Development of specialized groups for engineering project organizations. Traditional groups are shown above main divisions of project effort; newer group functions are shown below.

and a "service" department. Management heard both sides of the story and determined that all leaders involved were competent and right. So, the conclusion reached was that the organization must be wrong.

The service in question was purchasing and the dissension was on a number of issues. Purchasing had many rules to follow aimed at reduction of cost and avoidance of legal entanglement. Engineering wished to allow the vendors some freedom and to work with vendors' engineering in true co-operative spirit, with corresponding violation of these rules. Purchasing wished to reduce overhead to a minimum, resulting in a constant backlog of orders and inability to tabulate nonroutine analyses of status at engineering's whim.

Engineering felt that to delay a project a few days was far more costly than any number of clerks, and to operate without having full data was sinful.

The solution being tried is to automatize the routine work. The process chosen (1) preserves the engineer's original description, thus eliminating clerical errors; and (2) provides such mechanized records that any report wanted is obtained with negligible clerical labor. If the plan is fully carried out, the labor saving will permit much more personalized attention of purchasing agents to engineers' problems and needs.

The mechanization of routine solves the clerical help problem, provides better information, and frees skilled personnel to work on the many special problems requiring their attention. It also impersonalizes a portion of the service organization, thereby to some extent removing the emotional stress of fundamental conflicts. It's a step that small services can take toward the automatic, prompt, consistent and friendly atmosphere carefully nurtured by public utilities.

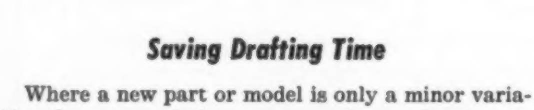
Overall Approach: Major problems faced by the organization that would engineer a series of large systems and their recommended solutions are summarized in *Organizing Large Engineering Projects*.

These may not be the best or even the right solutions but it is assured that solutions will be found. Large systems are being developed and permanent facilities for developing them are being founded. When these have matured they will provide the field of engineering and the country with a powerful force.

Tips and Techniques

Ready-Made Lettering Template

Lettering through a slot rather than on guide lines as described on Page 113 of the Oct. 18, 1956, issue of MACHINE DESIGN seems to be a good idea. In fact it's so good that the Dolgorukov Mfg. Co., 407 Fisher Bldg., Detroit 2, Mich., has been marketing a device very similar to that described for about 15 years. This should be good news for in-



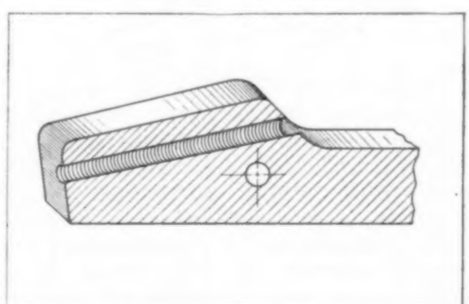
expert plastic whittlers who like the idea. The ready-made device incorporates reference lines for even letter spacing and a circular cutout for circling part numbers on drawings.

Saving Drafting Time

Where a new part or model is only a minor variation from an existing one, complete redrawing to full size is expensive. If a small copy of the existing item is available—reduced photocopy, catalog page, etc.—the new item may be wholly or partly traced and changes noted or drawn. Often such prints will be available on $8\frac{1}{2}$ by 11 in. or smaller sheets which will also reduce cost of prints made from the revised drawing.—JOHN W. HEALEY, *Cuyahoga Falls, O.*

Improved Lead Holder

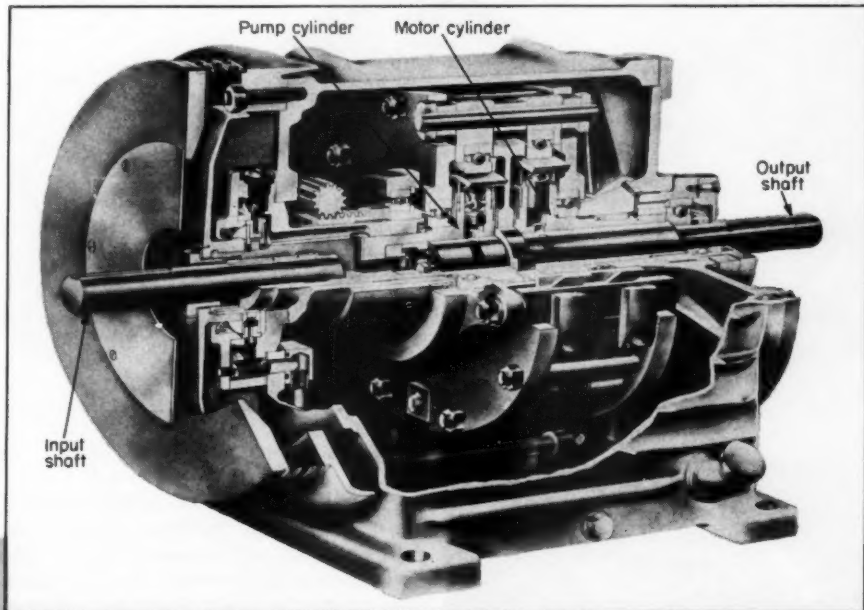
Lead-holding action of a compass may be improved by running a 2-56 or 1-64 tap through the hole in which the lead is clamped. Very little



tightening of the clamp screw will then hold the lead very tightly.—ERNST A. KREMEYER, *St. Joseph, Mich.*

Do you have a helpful tip or technique for our other readers? You'll receive ten dollars or more for each published contribution. Send a short description plus drawings, tables or photos to: Tips and Techniques Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

scanning the field for Ideas



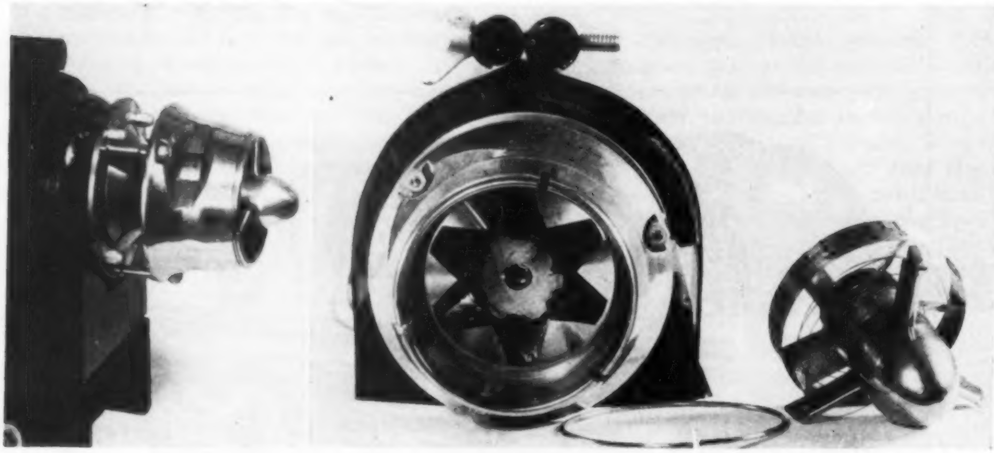
ADJUSTABLE CONTROL OF OUTPUT SPEEDS in a positive-displacement type hydraulic transmission is accomplished by simultaneously varying pump and motor stroke. In an infinitely variable unit developed by Carter Gears Ltd. (England), there is no oil flow at either zero or maximum output speed. Output speed is directly proportional to pump stroke which is maximum at maximum speed.

In construction, the transmission is composed of a multiple-piston input pump, a similar output motor unit, and an assembly for adjusting stroke of the pump and motor at any speed. The pump cylinder block is keyed to the input shaft whereas the motor cylinder block remains stationary. In the stroke-adjustment assembly are two eccentric elements in the form of ball-bearing races which are angularly displaced by 180 degrees and are connected by a web member to the output shaft.

Speed is adjusted by means of an external control shaft which mechanically moves the eccentric crank elements across the axis of the transmission. This action simultaneously increases pump stroke and decreases hydraulic motor stroke or vice versa. Thus at zero output speed, pump stroke is zero and motor stroke is maximum. At maximum output speed, pump stroke is maximum and motor stroke is zero. Oil flow is maximum at one-half of the maximum output speed.

IDEAS

ACCURATE MEASUREMENT OF SHAFT SPEEDS without mechanical or electrical contact is accomplished through the novel application of an axial flow fan. In a speedmeter developed by Boas J. Popper of Kfar-Ata, Israel, the airstream from an axial flow fan is used to rotate the speed indicator which consists of shrouded guide-vane unit. Deflection of the guide vanes, which can be rotated 300 degrees against a spring, is proportional to the square of the angular velocity of the fan.



SPIRAL-CURVE RECORDING OF DATA on multiple-channel magnetic memory drums simplifies electrical circuit requirements for processing information in digital form. Employed in a medium-speed, digital computer developed at Northrop Aircraft Inc., the recording technique permits considerable reduction of computer size. Through the use of a moving pick-off head mechanism, it is possible to record on or read from 64 magnetic memory-drum channels with only two pick-off heads. The heads are mounted on a transverse carriage which is geared to make one full cycle up and down the face of the memory drum in approximately 2 seconds. Each head records or reads along a spiral curve as it moves up or down while the memory drum revolves at the rate of 1800 rpm. The mechanism reduces pick-off circuitry requirements to about 3 per cent of that which would be required if separate heads were used for each of 64 channels.

Do you have a novel design idea for our other readers? You can receive ten dollars or more for each idea accepted for exclusive publication in this department. Send a short description plus drawings or photos to: "Scanning the Field for Ideas," MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

Methods for analyzing and designing

Pivoted-Shoe Radial Bearings

By Eugene J. Cattabiani
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Bearings with pivoted shoes or pads have several important advantages over plain journal bearings: they are self-aligning within certain load limits, shaft whirl is virtually eliminated, and liquids containing abrasive particles are more easily handled. Practical methods for designing three, four and six-shoe bearings are detailed here.

PIVOTED-SHOE or pivoted-pad radial bearings, Fig. 1, have several important advantages over plain journal bearings. Shaft whirl (oil film whirl or oil whip)[1] is almost completely eliminated, except at extremely light loads and high speeds. Pivoted-shoe bearings are inherently self-aligning, since the lubricant pressure is automatically "adjusted" by tilt of the shoe to compensate for moderate changes in load. Particles in suspension in the lubricant are quickly flushed out between the shoes; a full journal bearing has difficulty ridding itself of such particles.

The design study on which this article is based was aimed at the prevention of shaft whirl in canned motor-pumps. In these pumps, the radial bearings operate in a vertical position and are very lightly loaded. With a full journal bearing under these conditions, the shaft could conceivably "whirl," a condition in which the journal center rotates in an orbit about the center of the bearing. Excessive vibration then occurs and the load-carrying capacity of the bearing becomes so low that failure may result. Although shaft whirl has not created any failure to date, the lightly loaded conditions in canned motor-pump radial bearings do point to the possibility. The pivoted-shoe bearing is one answer to the potential problem. The self-aligning feature of the pivoted-shoe bearing also adds reliability, since water is the lubricant and film thicknesses are minute.

Pivoted-pad bearings have two principal disad-

[1]References are tabulated at end of article.

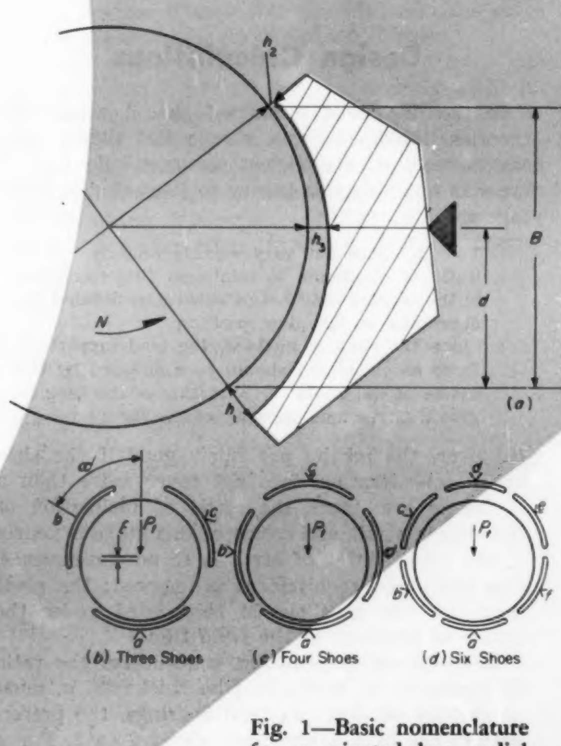

Fig. 1—Basic nomenclature for a pivoted-shoe radial bearing, and variations in number of shoes which can be used.

Nomenclature

a = Ratio of maximum to minimum film thickness, in./in.
$= h_1/h_2$
B = Shoe chord length, in.
C = Radial bearing clearance, in.
C_c = Bearing support factor
C_p = Bearing load factor
d = Distance of pivot and center of pressure from inlet end along chord of shoe arc, in.
h_1 = Maximum film thickness, in.
h_2 = Minimum film thickness, in.
h_3 = Film thickness under pivot, in.
L = Shoe axial length, in.
N = Shaft speed, rpm
P = Bearing shoe load, lb
P_t = Total load capacity of bearing, lb
Q = Side leakage correction factor
U = Velocity of bearing surface, in. per second
α = Angle between load and shoe pivot, degrees
ϵ = Eccentricity: radial distance between bearing and journal centers, in.
μ = Viscosity of lubricant, reyns

vantages: (1) for a given film thickness they have a lower load capacity than full journal bearings, except when film thicknesses are very small, and (2) they are more expensive to manufacture than plain full-journal bearings.

Design Calculations

In the design of a journal shoe bearing, the theories developed for a simple flat tilting shoe can be used with sufficient accuracy.[2] Sources of error in applying this theory to journal shoe bearings are:

1. The gap does not vary exactly linearly.
2. Ratio of maximum to minimum film thickness in the bearing may not be exactly as decided on, depending on the pivot position.
3. Since the shoe is inclined, the load-supporting force as calculated should be multiplied by the cosine of the angle of inclination of the shoe to give the true load capacity of the shoe.

However, the results are fairly good if the shoe under consideration does not cover more than a 90-degree arc. Since the angle of inclination of the shoe is small, and cosine of this angle is nearly 1, the third source of error is of no consequence. One additional requirement is imposed: the pivot point for the shoe should be located under the center of pressure of the fluid film.

In design of the bearing, a value for the ratio of maximum to minimum film thickness, a, must be decided on. For practical bearings, the preferable values of a range from about 2 to 3. For a particular set of conditions, a can be selected to give minimum power loss, maximum load capacity or optimum conditions for any of the usual bearing criteria. However, minimum power loss and highest capacity cannot be achieved in the same design.

Once a is decided, the load factor, C_p and support factor C_c can be evaluated:[2]

$$C_p = \frac{6}{(a-1)^2}\left[\ln a - \frac{2(a-1)}{a+1}\right] \qquad (1)$$

$$C_c = \frac{1}{C_p}\,\frac{6}{(a-1)^2(a+1)}\,[a\,(a+2)\ln a - 2.5\,(a-1)^2 - 3\,(a-1)] \qquad (2)$$

The bearing support factor from Equation 2 is used to determine location of the center of pressure, and consequently the pivot location,

$$d = BC_c \qquad (3)$$

while the load supported by each shoe can be determined from

$$P = \frac{\mu U B^2 L}{h_2^2}\,C_p\,Q \qquad (4)$$

The end leakage factor Q can be determined from Fig. 2, and

$$U = \frac{\pi DN}{60}$$

The only variable left unspecified is h_2, the minimum film thickness at the outlet end of the shoe. The following analysis shows how to determine this film thickness.

From the geometry of a plane slider bearing,

$$\frac{h_3 - h_2}{h_1 - h_2} = \frac{(B-d)(h_1 - h_2)}{B} \qquad (5)$$

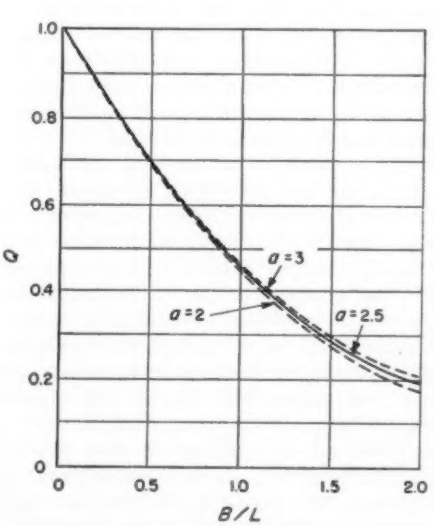

Fig. 2—Side-leakage factor, Q, for different bearing configurations, B/L, and film-thickness ratios, a (Reference 2).

and, as already determined,

$$h_1 = a\,h_2 \tag{6}$$

Combining Equations 5 and 6,

$$h_3 = \frac{(B-d)\,a + d}{B}\,h_2 \tag{7}$$

Except for the inclination of the shoes, the tilting shoe bearing can be regarded as a species of journal bearing in which the film thickness at the pivot location h_3 is the same as that of a plain journal bearing of the same dimensions. Thus, from conventional analyses,

$$h_3 = C + \varepsilon \cos \alpha \tag{8}$$

Combining this equation with Equation 7,

$$h_2 = \frac{B}{(B-d)\,a + d}\,(C + \varepsilon \cos \alpha) \tag{9}$$

The minimum film thickness occurs when α = 180 degrees, so cos α = -1. In this case,

$$h_m = \frac{B}{(B-d)\,a + d}\,(C - \varepsilon) \tag{10}$$

Since the bearings in question are used as guide bearings, the load may act in any direction. When the load passes directly through the center of one shoe, the bearing has its lowest load-carrying ability.[3]

Under this condition, the film thicknesses and loads for a three-shoe bearing, Fig. 1*b*, would be worked out as follows:

$$h_{2a} = \frac{B}{(B-d)\,a + d}\,(C + \varepsilon \cos 180)$$

$$= \frac{B}{(B-d)\,a + d}\,(C - \varepsilon)$$

$$h_{2b} = h_{2c} = \frac{B}{(B-d)\,a + d}\,(C + \varepsilon \cos 60)$$

$$= \frac{B}{(B-d)\,a + d}\,(C + 0.5\,\varepsilon)$$

From Equation 10, however,

$$\varepsilon = C - \frac{(B-d)\,a + d}{B}\,h_m$$

Therefore,

$$h_{2a} = h_m \tag{11}$$

$$h_{2b} = h_{2c} = 1.5\,\frac{B}{(B-d)\,a + d}\,C - 0.5\,h_m \tag{12}$$

The total load on the journal is analyzed as

$$P_t = P_a - P_b \cos 60 - P_c \cos 60$$

$$= P_a - 2\,P_b \cos 60$$

$$= P_a - P_b \tag{13}$$

For a four-shoe bearing, Fig. 1*c*, following the same type of analysis,

$$h_{2a} = h_m \tag{14}$$

$$h_{2c} = 2\,\frac{B}{(B-d)\,a + d}\,C - h_m \tag{15}$$

$$P_t = P_a - P_c \tag{16}$$

For a six-shoe bearing, Fig. 1*d*, the comparable equations are:

$$h_{2a} = h_m \tag{17}$$

$$h_{2c} = h_{2e}$$

$$= 1.5\,\frac{B}{(B-d)\,a + d}\,C - 0.5\,h_m \tag{18}$$

$$h_{2d} = 2\,\frac{B}{(B-d)\,a + d}\,C - h_m \tag{19}$$

$$h_{2b} = h_{2f}$$

$$= 0.5\,\frac{B}{(B-d)\,a + d}\,C - 0.5\,h_m \tag{20}$$

$$P_t = P_a + P_b - P_c - P_d \tag{21}$$

Practical Bearing Design

A pivoted shoe bearing has been designed as the lower bearing for the Westinghouse 4000-C canned motor pump. A three-shoe design was decided on, Fig. 3, with an individual bearing arc of 90 degrees. This leaves room between the shoes for a device to clamp the bearing insert.

Axial length of the bearing shoe to fit the motor pump is L = 4.5 in.; diameter is 3.375 in. Lubricant is water at 200 F for which $\mu = 3.84 \times 10^{-8}$ reyns. Rotational speed, N = 3600 rpm.

An optimum ratio of maximum to minimum film thickness, a, was decided on as 2.5. This sets the following values: C_p = 0.158 (Equation 1); C_c = 0.589 (Equation 2); and $h_1 = 2.5\,h_2$ (Equation 6).

The shoe arc covers 90 degrees, so

$$B = \frac{3.375}{2}\sqrt{2} = 2.39 \text{ in.}$$

d = 1.41 (Equation 3), and $h_3 = 1.615\,h_2$

Since B/L = 2.39/4.5 = 0.531-in., then Q = 0.69 from Fig. 2. Also, from the given conditions,

$$U = \frac{\pi\,(3.375)\,(3600)}{60} = 636 \text{ in./sec}$$

Therefore, the load on any shoe is, from Equation 4,

$$P = \frac{(3.84)\,(10^{-8})\,(636)\,(2.39)^2(4.5)\,(0.158)\,(0.69)}{h_2^2}$$

$$= \frac{68.44\,(10^{-6})}{h_2^2}$$

Minimum film thicknesses are, from Equations

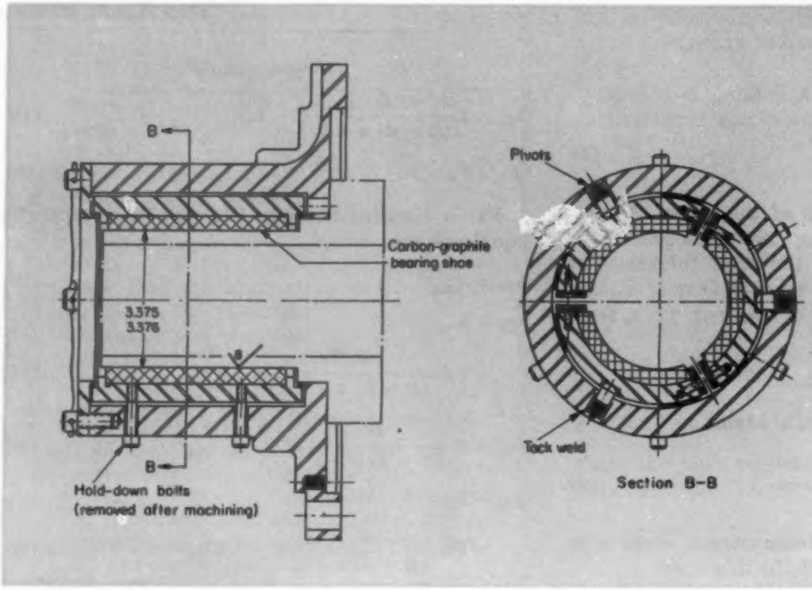

Fig. 3—Actual three-shoe bearing designed for the Westinghouse 4000-C canned motor-pump.

11 and 12,

$$h_{2a} = h_m$$

$$h_{2b} = h_{2c} = 0.93\,C - 0.5\,h_m$$

Total load capacity of the bearing is found from the previous three equations, and Equation 13:

$$P_t = P_a - P_b$$

$$= 68.44\,(10^{-6})\left(\frac{1}{h_m^2} - \frac{1}{(0.93\,C - 0.5\,h_m)^2}\right)$$

In this bearing design, radial bearing clearance C ranges from 0.003 to 0.004-in.

Bearing materials used, Fig. 3, are Graphitar No. 14 shoes (U. S. Graphite Co.) running against a journal of malcomized 17-4PH stainless steel (Armco Steel Corp.). The pivot has a cap with a minimum of 1/8-in. of Stellite No. 12 (Haynes Stellite Co.) for wear resistance. The rest of the assembly is all stainless steel.

The carbon-graphite segment in each shoe is compressed axially by shrinking it in the retainer and circumferentially by heating the assembly prior to fastening the end clips in place. Each shoe is then rigidly fastened to the bearing housing with four bolts by bolting down against 1/16-in. brass shims.

Shoe pivots are then tightened and locked in place with tack welds. The internal diameter is ground to the proper size and surface finish, and bolts and shims removed. The top bearing retainer is then bolted in place.

A bearing of this design has operated for over 1600 hours in a test loop with many starts and stops. Removed after this test period, the bearing was in near-perfect condition; it showed no wear and very little scoring.

Operation Under Abrasive Conditions: For slurries and similar "lubricants" containing abrasive particles, four or more shoes should probably be used. Materials might be solid Alundum shoes against a flame-sprayed Alundum or carbide journal. Then the bearing materials could be harder than the particles in suspension.

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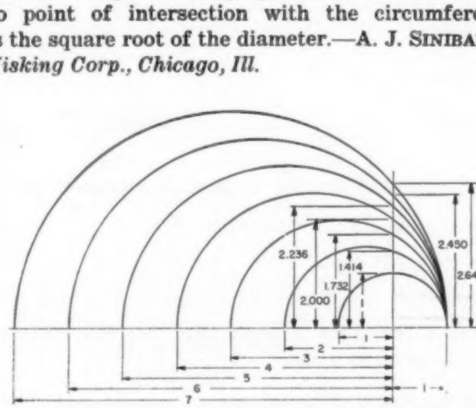
2. A. E. Norton—*Lubrication*, McGraw-Hill Book Co., Inc., New York, 1942, Pages 72-87 and 161.
3. John Boyd and A. A. Raimondi—"An Analysis of the Pivoted Pad Journal Bearing," *Mechanical Engineering*, May, 1953, Page 380.

Tips and Techniques

Graphical Square Roots

Lines equal in length to the square root of a number may be constructed by first drawing a semicircle equal in diameter to the number whose square root is to be found. Then erect a perpendicular to the diameter, one unit in from the circumference. Length of this perpendicular from diameter to point of intersection with the circumference is the square root of the diameter.—A. J. SINIBALDO, *Visking Corp., Chicago, Ill.*



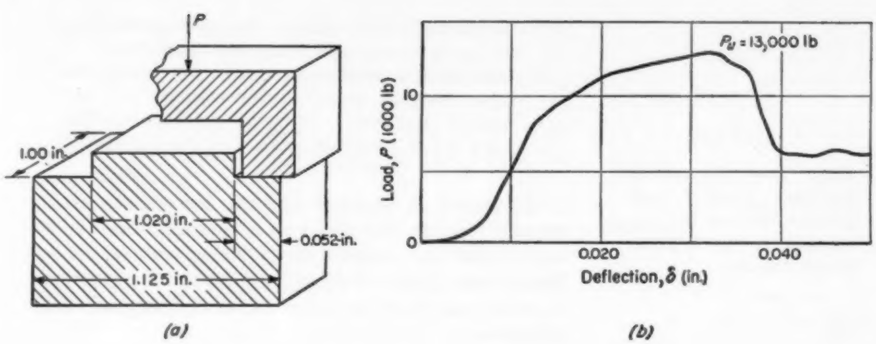


Fig. 1 — Straight groove wall or shoulder loaded by plane - faced sleeve showing, *a*, test assembly and, *b*, corresponding load - deflection diagram.

An analytical method for determining

Load Ratings of

Retaining Ring Assemblies

By Heinrich Heimann
Waldes Kohinoor Inc.
Long Island City, N. Y.

RETAINING or snap rings are designed to provide an artificial shoulder for locking or positioning components on shafts and in housing bores. For maximum resistance to axial thrust loads, rings are usually mounted in annular grooves although certain self-locking types permit application with ungrooved surfaces in light assemblies.

In the development of design data for groove-mounted ring assemblies, attempts have been made to establish load ratings not only for the rings themselves but also for the grooves in which they are seated. Conventional starting points for such analyses are usually two basic assumptions:

1. Ultimate thrust load to which a ring may be subjected depends upon its shear resistance; that is, shear strength of ring material times ring shear area.
2. Ultimate thrust load to which a groove may be subjected depends upon its compressive resistance; that is, compressive strength of groove material times area of groove wall.

For the first assumption, a safety factor of four is adequate in cases of repeated static loadings, as proved by tests and field experience. The second assumption, however, obviously includes an underestimation of groove strength since the reinforcing influence of the body of the shaft or housing is disregarded. Here, a relatively moderate safety

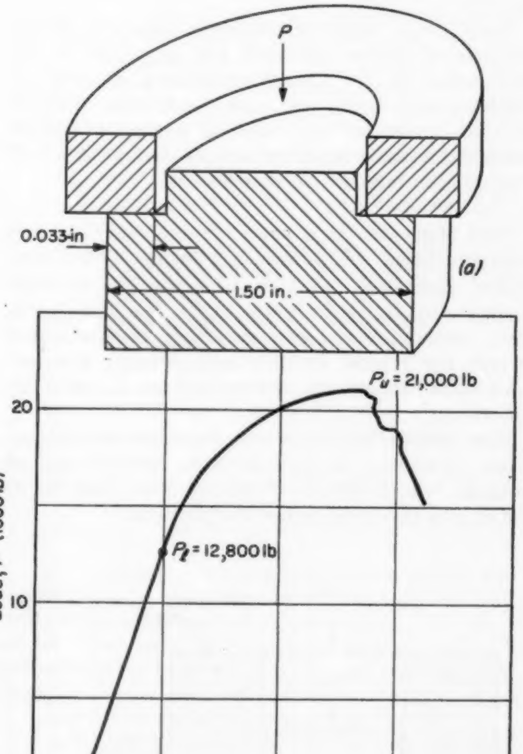


Fig. 2—Circular groove wall or shoulder loaded by plane-faced sleeve showing, *a*, test assembly and, *b*, corresponding load deflection diagram. Material is 2024-T4 aluminum.

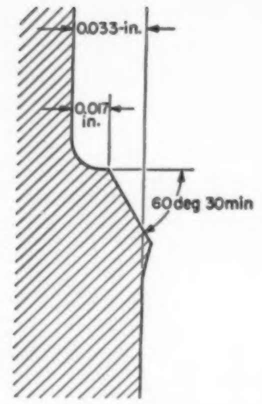


Fig. 3 — Magnified section profile of groove wall of test assembly in Fig. 2 after shear failure.

factor of three has been proposed for establishing permissible thrust load values for ring assemblies.

Degree of underestimation of groove strength inherent in the second assumption was recently measured by a series of tests. These tests have shown conclusively that the ultimate thrust capacity of a groove wall (that is, when it is totally deformed and partly sheared through) exceeds the value obtained from simplified calculations based on the foregoing assumption by at least 100 per cent.

Need for a more satisfactory approach to the problem of groove strength has prompted an investigation of the thrust resistance of ring assemblies under varying load conditions. Results of that investigation, including a new analytical method for determination of ring and groove load ratings, are reported in this article.

Test Methods: As a basis for analysis of groove characteristics, tests were performed under simplified conditions; that is, with the groove walls loaded directly with plane-faced machine parts. Test assemblies and corresponding load-deflection curves for typical straight and circular grooved-wall constructions are shown in Figs. 1 and 2, respectively.

The load-deflection curves for these assemblies, Figs. 1*b* and 2*b*, as well as those for full ring assemblies which will be discussed later, may be divided into three characteristic portions:

1. Initial deflection under moderate load to bring the parts to full grip with each other.
2. Load proportional deflection to a point that determines the so-called proportional limit load.
3. Rapidly increasing deflection to the breaking point which determines the ultimate thrust load, P_u, of the assembly.

As shown in Figs. 1*b* and 2*b*, test values of ultimate load P_u for the two assemblies are 13,000 and 21,000 lb, respectively. These values are at least twice those obtained by simplified calculation methods based on the second assumption previously discussed.

Groove Wall Behavior: But the most relevant information offered by the tests was on the behavior of the groove wall under ultimate load. Failure of the groove wall would normally be expected to occur at the inner, relatively sharp-cornered, edge by cracks or flaws induced by high stress concentration. However, under ultimate load, the groove wall sheared through on surfaces inclined at a certain angle γ, with failure starting inside the groove wall but at varying distances from the inner edge. Fig. 3 shows a magnified section profile of a sheared wall portion of the circular groove test assembly, Fig. 2. Material is 2024-T4 aluminum. Shear angle $\gamma \approx 60$ deg.

Thus, the conclusion seems justified that the surfaces of least resistance in a groove wall or shoulder are shear or slip surfaces inclined at some angle with the wall surface. Many tests on full ring assemblies of different sizes have verified this conclusion.

Groove Strength Analysis: Consider, for analysis, the simplified assembly shown in Fig. 4. Basic assumptions for this case are: (1) deformation or

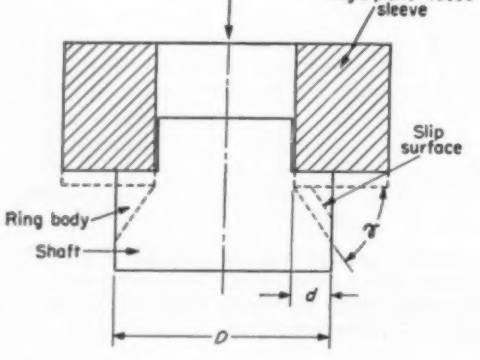


Fig. 4—Left — Simplified groove assembly for analysis of wall strength. Loading is accomplished through plane-faced sleeve.

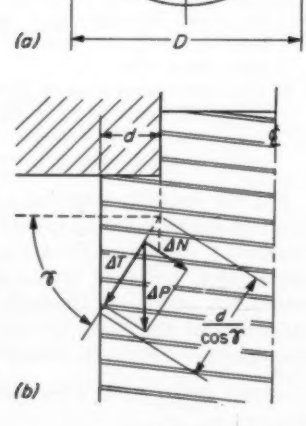


Fig. 5—Right—Basic relationships for analysis of groove wall element under load showing, *a*, plan view of groove wall or shoulder and, *b*, force diagram.

deflection of the groove wall is uniform, (2) probable distribution of specific pressure p is constant, (3) deformation of the groove wall is caused mainly by the slipping of the material along (conical) surfaces inclined at a certain angle, γ, and (4) angle γ depends on the internal friction along the slip surfaces.

If no internal friction existed, γ would be 45 deg. But this angle, as proved by many tests, exceeds 45 deg considerably (Fig. 3) due to the reinforcing influence of the internal friction of the groove material.

From an analysis of forces acting on a groove wall element, Fig. 5, it can be shown that

$$p\,(\sin\gamma\cos\gamma - \mu\cos^2\gamma) = \tau \qquad (1)$$

where symbols are defined in the accompanying Nomenclature.

Two conclusions may be drawn from Equation 1 which relates the specific pressure exerted by the plane-faced sleeve against the groove wall and the shearing strength of the groove material:

1. Ultimate pressure that can be applied to the groove wall depends not only on the shear strength of the groove material but, to a large extent, also on the coefficient of internal friction.
2. Shear angle γ is that angle for which the normal pressure p is a minimum. That is, the expression, $\sin\gamma\cos\gamma - \mu\cos^2\gamma$, becomes a maximum.

From Equation 1, setting the first derivative of the expression in parentheses equal to zero and solving to find a maximum gives:

$$\mu = -\cot 2\gamma \qquad (2)$$

Thus, if either μ or γ are known, the other unknown quantity can be readily calculated from Equation 2. For 2024-T4 aluminum, slip or shear angle of the groove construction shown in Fig. 4 is approximately 60 deg, Fig. 3. From Equation 2, then, the coefficient of internal friction is approximately 0.58.

Combining Equations 1 and 2 and solving for P_u gives:

$$P_u = 2\tau d\pi D\tan\gamma \qquad (3)$$

For the 2024-T4 aluminum groove construction, where γ is approximately 60 deg, Equation 3 becomes:

$$P_u \approx 10dD\tau$$

If γ = 45 deg, $\tan\gamma$ = 1 and, from Equation 2, μ = 0. Thus, the ultimate thrust resistance of a groove wall or shoulder where there is no internal friction would be

$$P_u = 2dD\pi\tau$$

For example, in a groove construction with the dimensions shown in Fig. 2 where τ = 40,000 psi (2024-T4 aluminum) and slip angle is 60 deg, P_u = 10 (0.33) (1.5) (40,000) = 20,000 lb. This calculated result is quite close to the tested value of

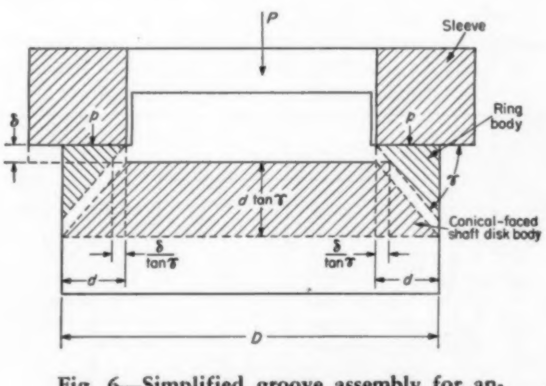


Fig. 6—Simplified groove assembly for analysis of deflection under load. Circular groove wall or shoulder is loaded by plane-faced sleeve and abutted by conical-faced shaft disk body. Cone angle is γ.

Nomenclature

- b_r = Average width of retaining ring section, in.
- D = Shaft diameter, in.
- D_n = Diameter of neutral axis of retaining ring, in.
- d = Radial width or depth of groove wall or shoulder, in.
- d_e = Effective groove width or depth, in.
- E = Modulus of elasticity of groove wall material, psi
- E_r = Modulus of elasticity of retaining ring material, psi
- G = Shear modulus of elasticity for groove wall material, psi
- h = Distance between points of application of thrust load and reaction force on retaining ring, in.
- ΔN = Normal component at slip surface of axial load on groove wall element, lb
- P = Thrust load, lb
- ΔP = Axial load on groove wall element, lb
- P_l = Proportional limit load on groove wall corresponding to yield strength in shear of groove material, lb
- P_u = Ultimate or maximum allowable load on groove wall at failure, lb
- p = Unit load or specific pressure on groove wall
- s_r = Bending stress in middle section of ring, psi
- ΔT = Tangential component, along slip surface, of axial load on groove wall element, lb
- t = Thickness of retaining ring, in.
- γ = Shear angle of groove wall material, deg
- δ = Groove wall deflection, in.
- δ_m = Maximum groove wall deflection, in.
- κ = Yield strength in shear of groove wall material, psi
- μ = Coefficient of internal friction for groove wall material
- ν = Poisson's ratio
- τ = Maximum shear strength of groove wall material, psi
- ϕ = Angle of deflection of groove wall, deg

21,000 lb (Fig. 2*b*).

When the thrust load is not increased up to the value determined by maximum shear strength of the material, but only up to the yield strength in shear, κ, it can be concluded that deflection is purely elastic because at no point on the groove wall is the yield strength of the material in shear exceeded. Also, the relationship of proportional limit load for the groove wall to ultimate load is given by the ratio, κ/τ. Therefore, the expression for the proportional limit load in this specific case, Fig. 4, is

$$P_l = 2\kappa d\pi D \tan\gamma \qquad (4)$$

For $\gamma = 60$ deg (2024-T4 aluminum), Equation 4 becomes

$$P_l \approx 10dD\kappa$$

For the assembly shown in Fig. 2, with $\kappa = 24{,}000$ psi (2024-T4 aluminum), $P_l = 12{,}000$ lb. This result agrees closely with the tested value, Fig. 2*b*, of $P_l = 12{,}800$ lb.

It should be mentioned that fracture of the groove wall under ultimate load does not necessarily start at the inner edge of the groove wall. It may, in fact, start at any point between the outer and inner groove wall edges because any of the possible slip surfaces are subjected to equal working stresses. But this has no bearing on the equations for ultimate or proportional limit load, much in the same manner as the case of a tensile test where it is irrelevant at which exact spot of its length the fracture of a tensile test specimen occurs.

As compared to load calculations based on Equations 3 and 4, a wide range of actual load values may be expected for the different specimens even of one random test sample. This variation results because the coefficient of internal friction and, therefore, the tangent of slip angle γ may vary considerably from one test specimen to another, and even from one section of a groove wall to another in the same test specimen.

Moreover, it is of importance to recognize that the allowable thrust load of a groove wall as calculated from the simplifying assumption discussed initially, using a safety factor of 3, equals closely the allowable thrust load as calculated with Equation 3, using a safety factor of at least 6.

Groove Wall Deflection: The next problem to be analyzed for the circular groove assembly, Fig. 2*a*, is that of groove wall deflection under a limit load; that is, up to the point where proportionality between load and deflection ceases, Fig. 2*b*. As depicted in Fig. 6, it is assumed that a sleeve presses against the groove wall of depth *d* with thrust load *P*, creating uniform pressure *p*. The triangular ring body, limited by a conical slip surface inclined at angle γ, is abutted by the correspondingly conically faced disk body of the shaft.

Based on the volume of the groove wall displaced by the sleeve, an approximate expression for groove wall deflection can be derived:

$$\delta \approx \frac{\kappa}{E}(1-\nu)\, D \tan^2\gamma \qquad (5)$$

Two conclusions, which have been confirmed by test results, may be drawn from this approximate deflection equation:

1. Deflections are independent of groove depth *d* because the thickness of the abutting shaft disk body increases proportionally with increasing groove depth.
2. Variations between minimum and maximum deflections in tested samples can be expected to be very large because of possible variations of internal friction and, consequently, of the square of the tangent of the slip angle.

Calculated deflection values, using Equation 5, show good correlation with test results. For example, in a circular groove assembly, Fig. 2, of 2024-T4 aluminum, deflection under test is $\delta = 0.007$-in. From Equation 5, $\delta = 24{,}000\ (10)^{-7}\ (0.7)\ (1.5)\ (1.732)^2 = 0.0075$-in.

A simplified form of Equation 5 is

$$\delta = \frac{\kappa D}{G} \qquad (6)$$

which is based on $\gamma \approx 62$ deg and $\nu = 0.3$.

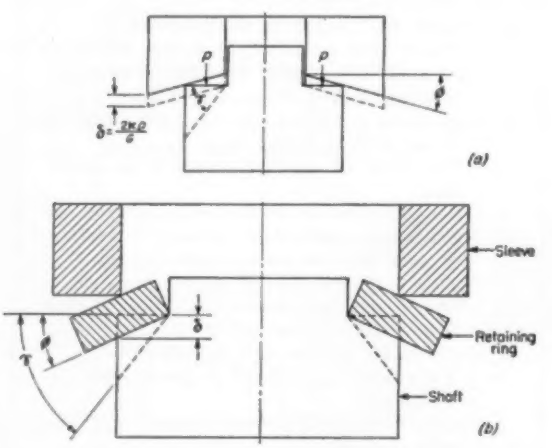


Fig. 7—Groove assemblies with basically similar load characteristics. At *a*, loading is accomplished by a sleeve with countersunk face; at *b*, load is transmitted to the groove wall through an intermediate retaining ring.

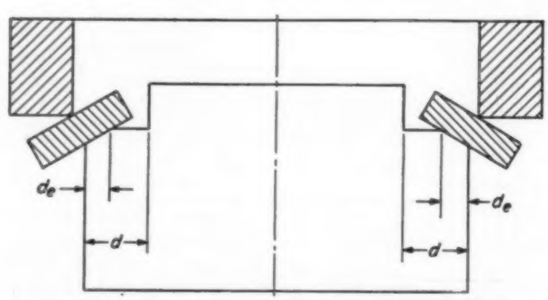


Fig. 8—Basic relationships for retaining ring assembly in which ring member is of relatively small thickness.

From Equation 5, for 2024-T4 aluminum with $\gamma = 60$ deg, $\delta = 0.005\ D$. From Equation 6, which corresponds to a slip angle of 62 deg, $\delta = 0.006\ D$. Thus, where the slip angle is approximately 60 deg as in the foregoing example, Equation 6 will give deflection values about 20 per cent greater than those obtained with Equation 5.

Design evaluation of retaining ring assemblies should be based on the upper limit of deflection and on the lower limit of load. For this reason, it is advisable to use Equation 6 for assemblies of the type shown in Fig. 2.

Effect of Countersunk Sleeve Face: Before investigating a full ring assembly, it is advantageous to consider a second intermediate fixture comprising a groove wall or shoulder loaded by a sleeve with countersunk face, Fig. 7*a*. The end configuration assumed here shows the groove wall deflected under angle ϕ. Pressure distribution is triangular with zero pressure at the inner groove edge and linearly increasing pressure to the outer edge.

The same end configuration results for a groove wall on which load is applied through a sleeve acting on an intermediate retaining ring which dishes out under the thrust exerted on it by the machine part, Fig. 7*b*.

Thus it seems justified to assume that load equations developed for assemblies of the type shown in Fig. 7*a* apply also to full ring assemblies, Fig. 7*b*.

In Figs. 7*a* and *b*, failure of the groove wall under ultimate load again occurs along slip surfaces inclined at some angle γ. In both cases, as in the assembly shown in Fig. 2, ultimate and limit loads can be determined from Equations 3 and 4.

If the maximum deflection at the outer groove edge equals δ_m and the deflection at the inner groove edge equals zero, then mean deflection $\delta = \delta_m/2$. Thus, at limit load, P_l, deflections of the two assemblies shown in Figs. 7*a* and *b* are

$$\delta_m = 2\delta = \frac{2\kappa D}{G} \tag{7}$$

For these two types of assemblies then, Equation 7 replaces Equation 6 for deflection calculations. If the groove wall material is again 2024-T4 aluminum, Equation 7 becomes $\delta = 0.012\ D$.

For a plane-faced rigid sleeve, Fig. 2, where mean and maximum deflection are the same, yield strength in shear is not exceeded at any point on the groove wall up to the proportional limit load. Therefore, the deflection falls practically into the elastic range.

This condition, however, is not true for the triangularly shaped deflection distribution (Fig. 7) under a corresponding proportional limit load, because near the outer edge of the groove wall the yield stress in shear is greatly exceeded. Even if the relationship between load and deflection up to the proportional limit load remains linear, near the outer edge of the groove wall there is a zone of plastic deformation which, upon release of load, results in a permanent set.

However, if only half of the calculated proportional limit load (Equation 4) is applied to the groove wall, with δ_m reduced correspondingly, and the yield strength in shear is not exceeded at the outer edge of the groove wall, plastic deformation and permanent set will be avoided.

The angle of countersink of the rigid sleeve for which the limit load P_l is not exceeded is given by:

$$\phi = \tan^{-1}\left(\frac{2\kappa D}{Gd}\right) \tag{8}$$

If ϕ is a small angle, then, in radian measure,

$$\phi \approx \frac{2\kappa D}{Gd} \tag{9}$$

If the ratio of shaft or housing diameter to groove depth, D/d, is maintained approximately constant, the countersink angle ϕ will also remain constant and independent of the size of shaft or housing.

Retaining Ring Stresses and Deflections: If a re-

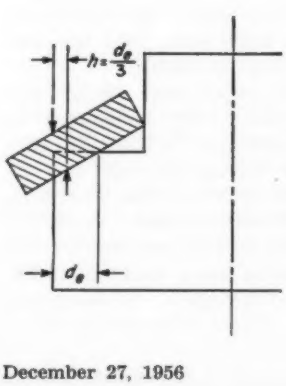


Fig. 9 — Section profile of dished-out retaining ring on deflected shoulder or groove wall.

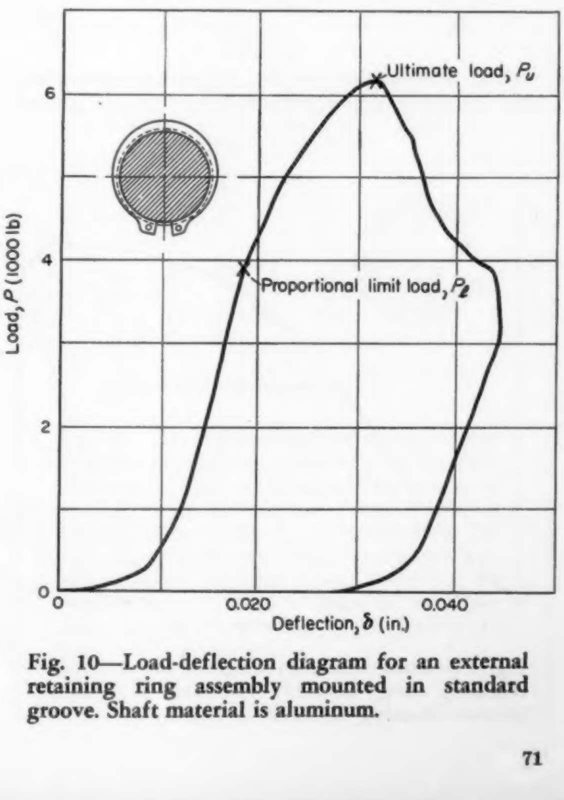


Fig. 10—Load-deflection diagram for an external retaining ring assembly mounted in standard groove. Shaft material is aluminum.

taining ring has large thickness it acts like a rigid sleeve, Fig. 2. With decreasing ring thickness, the condition depicted in Fig. 7 is approached. Finally, as thickness decreases further, the deflected ring abuts only a portion, d_e, of full groove depth d, Fig. 8. The latter case will now be investigated.

Assumptions for this analysis are:

1. Section width of the ring is constant. (For rings of diminishing section width, the mean width can be substituted.)
2. Load is uniformly distributed along the outer ring edge while the reaction acts uniformly on the inner ring edge. If these forces do not act on the ring edges, as is usually the case, their value has to be multiplied by the ratio b_r/h.

Relationship between ring stresses and applied thrust load is

$$P = s_r t^2 \frac{b_r}{h} \tag{10}$$

Angle of deflection ϕ of ring body can be determined from

$$\sin \phi = \frac{s_r D_n}{E_r t} \tag{11}$$

and if ϕ is small,

$$\phi = \frac{s_r D_n}{E_r t} \tag{12}$$

in radian measure.

Fig. 2 shows that $D_n \approx D$. Thus, $\phi = S_r D/(E_r t)$. Combining Equations 10 and 12 and substituting D for D_n gives the load-deflection equation

$$P = \frac{\phi E_r t^3 b_r}{Dh} \tag{13}$$

Ring Assemblies: In the preceding discussion, load and deflection equations for rings and groove walls were derived independently. But when a ring is seated in its groove and loaded by a machine part, two conditions exist:

1. Deflection of the ring must equal deflection of the groove wall.
2. Thrust load on the ring is transmitted to the groove wall so that the reaction force at the groove wall must equal the thrust load.

These two conditions indicate that groove depth and ring thickness are more or less interdependent. If the active groove depth is smaller than a certain fraction of the ring thickness, the proportional limit load depends on this active groove depth.

Table 1—Proportional Limit Loads for Typical Retaining Ring Assemblies

Nominal Size (in.)	Tested Load (lb)	Calculated Load (lb)	Difference (per cent)
Internal Rings			
⅝	2,600	2,700	+ 4
1⅜	11,600	10,500	−10
2⅜	37,200	41,600	+12
4	72,800	73,200	+ 0.6
External Rings			
1½	13,800	12,600	− 9
2	21,200	20,600	− 3

But, if the active groove depth is larger than a certain fraction of the ring thickness, the proportional limit load depends on this fraction of ring thickness. This fraction of thickness, in turn, depends on the material of the ring and the material of the groove.

The ring, after deflection, may take a position in the groove, Fig. 9, so that it covers only a part, d_e, of the groove width. If pressure distribution on this effective groove width is triangular, $h = d_e/3$. Combining ring and groove deflection and load equations then,

$$d_e = t \sqrt[3]{\frac{E_r b_r}{GD \tan \gamma}} \tag{14}$$

Thus, effective groove width d_e is a function of the ratios E_r/G and b_r/D. For a typical commercial retaining ring design, values of d_e for different materials are: steel, $d_e \approx 0.5t$; aluminum, $d_e \approx 0.7t$; and magnesium, $d_e \approx 0.83t$.

It is apparent that, to find the proportional limit load for the ring assembly, minimum groove depth must be compared with the effective groove depth and the smaller value chosen for P_l calculations, Equation 4. The same holds true for ultimate load calculations with Equation 3.

Calculated and test values of proportional limit loads for several different ring assemblies of 2024-T4 aluminum are compared in Table 1. Load-deflection diagrams for typical external and internal ring assemblies are shown in Figs. 10 and 11. Results obtained by test and calculation verify the validity of the assumption that the internal friction of the groove wall material has a major quantitative influence on the load ratings of retaining ring assemblies.

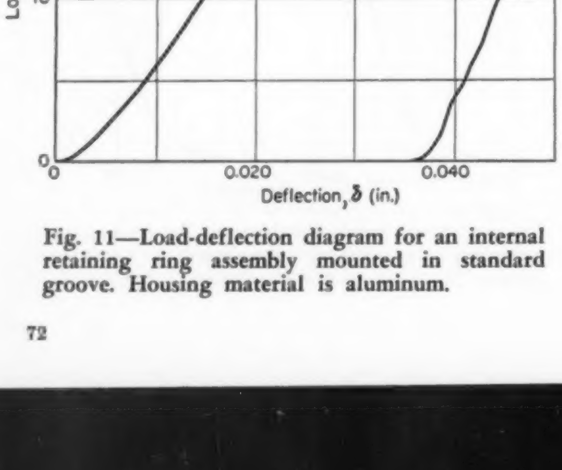


Fig. 11—Load-deflection diagram for an internal retaining ring assembly mounted in standard groove. Housing material is aluminum.

Hydraulic Servo Components—3

. . . their effect on system performance

Power Drives

- **Valve-controlled cylinder**
- **Pump-controlled motor**

By J. M. Nightingale
Manchester, England

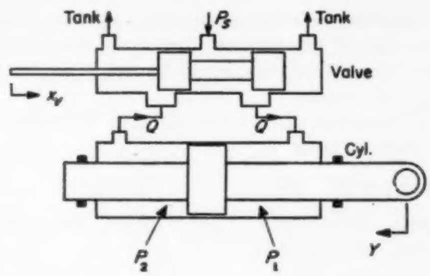


Fig. 21—Basic components of one type of power drive often used in hydraulic servo systems are a control valve and hydraulic cylinder. This article includes a mathematical analysis of the performance of such a system.

SINCE automatic-control or servo system performance is, in final analysis, the resultant of the performance of the various system components, an understanding of component characteristics is essential. This article will consider power drives, the muscles of a system. Other system components have been discussed in Parts 1 and 2.

In hydraulic servos, the power drive consists of a power source, a control valve or main amplifier and the servo motor. Function of the power drive is to produce the required output displacement and overcome any opposing loads. Because these loads are usually large, and power amplification always involves time lags, the power drive usually determines the performance of the servo as a whole.

Basic design considerations for two types of hydraulic drives will be considered. These are: (1) constant-pressure source plus flow-control valve plus cylinder-type displacement motor and (2) variable-delivery pump plus rotary-displacement motor. Occasionally, other combinations are used, for instance, a variable-delivery pump and a cylinder motor.

Valve-Controlled Cylinder: Design parameters of

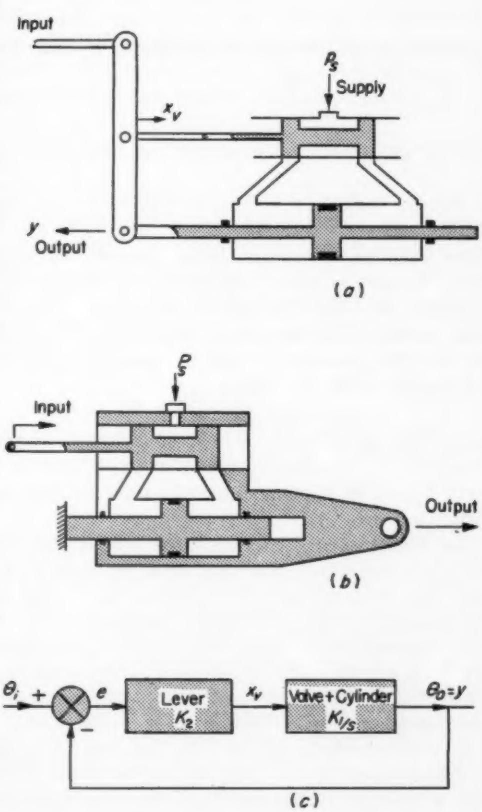


Fig. 22—A valve-cylinder servo system power drive requires a feedback system to close the loop. Either a lever differential, *a*, or virtual feedback resulting from a floating valve-cylinder body, *b*, are often used. Devices such as preamplifiers, transducers, etc., may also be included in the loop, but are omitted here. A block diagram of the power drive shown at *a* using lever differential feedback is shown at *c*.

this combination needed to satisfy the power requirements will be determined. Basic components of the system are shown in Fig. 21. In order to obtain explicit expressions for these design values, various simplifications must be made in the theoretical approach.

Flow from the supply line through the right-hand valve port is given by

$$Q = f(x_v)\sqrt{P_s - P_1} \tag{15}$$

Similarly, flow from the cylinder through the left-hand valve port is

$$Q = f(x_v)\sqrt{P_2} \tag{16}$$

If compressibility and leakage effects are neglected, these two flow rates must be equal. Equating them gives

$$P_1 + P_2 = P_s \tag{17}$$

Since the differential pressure acting on the cylinder piston is

$$P_c = P_1 - P_2 \tag{18}$$

Equations 17 and 18 may be combined to show that

$$P_s - P_1 = P_2 = \frac{P_s - P_c}{2} \tag{19}$$

Substituting this value of P_2 in Equation 16,

$$Q = f(x_v)\sqrt{\frac{P_s - P_c}{2}} \tag{20}$$

The function $f(x_v)$ describes the way in which the valve port is uncovered as the valve stroke x_v is varied. Making each valve port a row of spaced holes permits approximation of a desired function. But for the moment it will be assumed that the relationship is linear. Then

$$Q = \frac{Cax_v}{X}\sqrt{\frac{P_s - P_c}{2}} \tag{21}$$

where $C = 100$ if other quantities are in lb-in.-sec units.

This equation shows that flow varies not only with valve travel x_v, but also with pressure P_c and hence with the cylinder load. Thus, in normal circumstances, dynamic output loading on the cylinder piston introduces a nonlinearity into the system equations which must be taken into consideration. However, for this analysis the output load will be considered constant. Flow is then proportional to valve displacement. Flow into the jack is given by Equation 8 ($Q = Ady/dt$). Then from Equations 8 and 21 it follows that the transfer function relating valve displacement to cylinder displacement is

$$\frac{y}{x_v}(s) = \frac{K_1}{s} \tag{22}$$

where $$K_1 = \frac{Ca}{AX}\sqrt{\frac{P_s - P_c}{2}}$$

In order to complete the servo the loop must be closed. Often, this will include other components such as preamplifiers, transducers and so on. In many cases, however, the loop contains only the valve and cylinder, and is closed either by a lever differential, Fig. 22*a*, or by virtual feedback, Fig. 22*b*. This type of closed-loop system is a servo in itself, but it is sometimes used as a preamplifier in a more complicated system.

Other system components may be represented by a scalar gain K_2. Note that for the system shown in Fig. 22*b*, $K_2 = 1$; while in Fig. 22*a*, K_2 depends only on the lever ratios. In these cases the approximate theory is reliable. It should be noted, however, that time lags in other components approaching that of the power drive may make this approach inaccurate.

Loop transfer function of the system, Fig. 22*c*, is

$$Y_0(s) = \frac{K_1 K_2}{s} \tag{23}$$

The overall transfer function is, therefore,

$$Y_c(s) = \frac{1}{1 + Ts} \tag{24}$$

where $T = 1/K_1K_2$.

In any specific application, system pressure P_s, cylinder stroke L, maximum cylinder load F and certain operating times would probably be known. Design quantities to be obtained would then be cylinder piston area A, working pressure P_c, pump delivery Q_s, valve travel X and valve port area a.

Power delivered to the cylinder is proportional to

Nomenclature

A = Effective cylinder piston area
a = Total exposed valve port area, corresponding to $x_v = X$
C = Constant
F = Maximum cylinder load
$f(x_v)$ = Function describing how valve port area varies with x_v
K_1, K_2 = Gain constants
L = Cylinder stroke
L_p = Maximum pump control lever displacement
N = Angular speed
P_c = Differential cylinder pressure
P_s = System supply pressure
P_1 = Pressure on inlet side of cylinder
P_2 = Pressure on outlet side of cylinder
Q, Q_2, Q_n = Flow rates
s = Laplace operator
V_p = Pump displacement per revolution
V_m = Motor displacement per revolution
X = Maximum valve travel from neutral
x_p = Pump control lever displacement
x_v = Valve displacement from neutral
$Y_c(s)$ = Overall transfer function
$Y_o(s)$ = Loop transfer function
y = Cylinder displacement from neutral
$(y/x_v)(s)$ = Transfer function
θ_i = Input displacement
θ_o = Output displacement
ω_b = Frequency bandwidth
ω_c = Frequency limit for accurate response

$P_c\sqrt{P_s - P_c}$ and is maximum when $P_c = 2/3\,P_s$. Therefore, maximum operating pressure should be two-thirds of the supply pressure, since maximum power is needed at full load to get the best possible performance. This fixes the effective piston area, which is obtained from

$$A = \frac{3F}{2\,P_s} \tag{25}$$

This figure for maximum pressure is satisfactory for another reason. If a higher operating pressure were chosen, performance at high loads would be very sluggish, since the valve flow would saturate and the motor stall.

Although Equation 24 shows the unit to be linear, this is so only while the valve is not fully open. There is an error $E = X/K_2$, above which the output velocity remains constant, since the full valve port area is exposed. Normally E is a small fraction of the total output travel, which is the piston stroke L. Therefore, the response to an input step function of amplitude L, takes the form shown in Fig. 23. Over most of the stroke the valve is fully open and the output velocity constant. But as soon as the error is reduced to E, the valve begins to close and the output velocity decreases exponentially to zero.

Time for total stroke is given approximately by

$$T_0 = T_s + 2\,T \tag{26}$$

Substituting from Equations 22 and 24 for T gives

$$T_0 = \frac{AL}{Q_s}\left(1 + \frac{X}{K^2L}\right) = \frac{AL}{Q_s}\left(1 + \frac{E}{L}\right) \tag{27}$$

where Q_s, the saturated flow from the valve, is

$$Q_s = Ca\sqrt{\frac{P_s - P_e}{2}} \tag{28}$$

Total time, T_o, varies with the output load. It is generally specified for the no-load condition as one of the design requirements. In this case it is

$$T_n = \frac{3\,FL}{2\,CaP\sqrt{\dfrac{P_s}{2}}} \tag{29}$$

provided E/L is small.

In the full-load case, operating time is a minimum when $P_c = 2/3\,P_s$, and is equal to $\sqrt{3}\,T_n$. Therefore, the valve port area is

$$a = \frac{0.02\,FL}{T_n(P_s)^{3/2}} \tag{30}$$

when all quantities are in lb-in.-sec units.

Maximum flow demanded from the supply occurs under no-load, and is

$$Q_n = \frac{3\,FL}{2\,P_s\,T_n} \tag{31}$$

All the required parameters have now been determined except the valve stroke X. This limits the region within which the system is completely linear. The approximate frequency response bandwidth within this zone is given by

$$\omega_b = \frac{K_2\,L}{T_n\,X} \tag{32}$$

Thus for signals of approximate amplitude $E = X/K_2$, and for frequencies up to ω_b, the output is a fairly faithful reproduction of the input. For any greater input signal of magnitude θ_i, frequency response is limited by flow saturation of the valve. Accurate response can be obtained up to a frequency

$$\omega_c = \frac{L}{|\theta_i|T_n} \tag{33}$$

Above this frequency the response is not only attenuated, but is also distorted due to the nonlinear

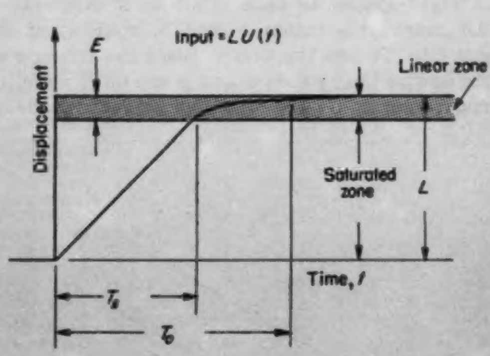


Fig. 23—Despite indications that the valve-cylinder power drive is linear, this is true only when the valve is not fully open. When the valve is fully open, output velocity is constant, due to saturation. This curve shows response to step function input of amplitude L.

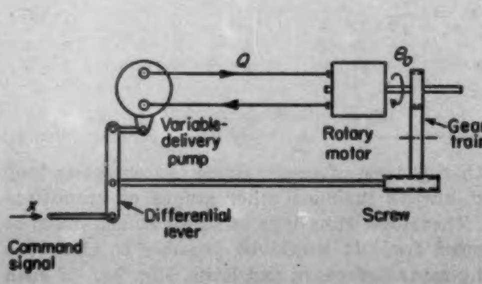


Fig. 24—A variable-delivery hydraulic pump and a fixed displacement rotary hydraulic motor are often used as the power drive in a servo system. Occasionally, other combinations such as a variable-displacement pump and a cylinder may be used. However, they are less common than this combination. A gear and lever system may be used to provide feedback in such a system.

effect of saturation. Typical values of ω_b and K_2 result in the ratio X/L being about 1/20.

Substituting for the unknown parameters in terms of the known in Equation 24 gives the following expression for the time constant of the overall response:

$$T = \frac{3\,FE}{Q_s P_s} \qquad (34)$$

In other words, the time constant is proportional to the output force, and width of the linear zone, and is inversely proportional to the power supplied by the source. This shows the penalty which must be paid.

Assuming that $P_s = 3000$ psi, $F = 4000$ lb, $L = 2.0$ in., $T_n = 0.25$ sec and $\omega_b = 80$ radians per sec for the system shown in Fig. 22*b*, where $K_2 = 1$, unknown parameters can be obtained from Equations 25, 30, 31 and 32. They are: $A = 2$ sq in., $a = 0.0039$ sq in., $Q_s = 16$ cu in. per sec, and $X = 0.1$ in. Time constant is, at no load, $T = 0.0125$ sec. The overall response function is approximately

$$\frac{\theta_0}{\theta_i}(s) = \frac{1}{1 + 0.0125s}$$

This analysis is only a rough approximation of dynamic system behavior when there is considerable variation in output loading. However, when output loads are comparatively small, this method offers sufficient accuracy.

Pump-Controlled Motor: Basic components are shown in Fig. 24. The flow equations, neglecting compressibility and leakage for pump and motor, respectively, are

$$Q = \left(\frac{NV_p}{60L_p}\right) x_p \qquad (35)$$

$$\theta(s) = \frac{1}{2\pi V_m}\frac{Q(s)}{s} \qquad (36)$$

Combining these shows that the relation between motor rotation and pump lever displacement is

$$\frac{\theta}{x_p}(s) = \frac{K_1}{s} \qquad (37)$$

where

$$K_1 = \frac{V_p}{V_m}\left(\frac{N}{120\,\pi L_p}\right)$$

With this type of power drive the complete loop almost always includes other stages of amplification. Therefore, time lags of these stages must be accounted for. It would be possible to close the loop by means of gears and lever, Fig. 24. If such a sysem is used, the overall transfer function is

$$\frac{\theta_0}{\theta_i}(s) = \frac{1}{1 + Ts} \qquad (38)$$

where

$$T = \frac{V_m}{V_p}\left(\frac{120\,\pi L_p}{NK_2}\right)$$

and K_2 = the feedback system constant. This is very similar to the result obtained for the relay. However, this also is a rather oversimplified picture of the behavior of these units. Effects of compressibility and leakage in the pump, motor and circuit seriously impair performance. Other components also have characteristics which affect the system, for instance, backlash in the gears, and time lags in the preamplification stages. A future article will analyze in some detail more complex hydraulic servos built up of the units considered in this article.

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This article is the eighth in a co-ordinated group by J. M. Nightingale on servo systems. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

1. "Automatic Control Systems" ....May 17, 1956
2. "Servo Mathematics" ....June 28, 1956
3. "Evaluating Servo System Performance—Part 1" July 26, 1956
4. "Evaluating Servo System Performance—Part 2" Aug. 9, 1956
5. "Analyzing Servo Systems" ....Nov. 1, 1956
6. "Hydraulic Servo Components—Part 1" ....Nov. 29, 1956
7. "Hydraulic Servo Components—Part 2"..........Dec. 13, 1956

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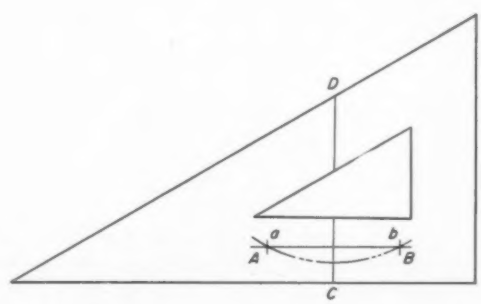
Tips and Techniques

Locating Arc Centers

A most used triangle can be easily converted into a device for locating centers of unknown arcs. Two lines *AB* and *CD* are scribed on the triangle at right angles to each other as shown. On line *AB* mark two points *a* and *b*, equidistant from line *CD*. To use the device, place the triangle over the arc so that points *a* and *b* are on the arc, then mark points *C* and *D*. Shift the triangle and



repeat the process. Now join the points to make two intersecting straight lines. The point of intersection of the lines is the center of the arc.—PETER DITORO, *New York, N. Y.*

Selecting Plastic Laminates and Vulcanized Fiber

WITH so many basic engineering materials now available, the task of choosing the right material is increasingly difficult. This problem is further complicated by the fact that similar materials may offer a wide variety of grades and characteristics. Two such materials are vulcanized fiber and laminated plastics. A selection chart, Table 1, can be extremely useful in choosing the proper grade of these materials for a particular application. Information for this table was supplied by R. F. Bogart, application engineer, National Vulcanized Fibre Co.

Vulcanized fiber is converted cotton with a tough, dense structure. A low cost material, it has: (1) excellent mechanical and good dielectric strength, (2) unique arc expulsion properties, (3) excellent machining and forming qualities. Vulcanized fiber is manufactured in many grades and forms with varying degrees of hardness, flexibility, resilience, drawing, forming, and punching qualities. These properties may be modified to meet new and specific conditions, needs and uses. In addition to the three grades of fiber listed in Table 1, there are many other special grades of this material.

Laminated plastics are thermosetting high-pressure laminates composed of various base materials and thermosetting resins. Fibrous materials, such as paper, cotton fabric, nylon, asbestos, glass fabric, cotton and glass mats are first impregnated with phenolic, melamine, polyester, epoxy or silicone resins and then bonded under high pressure to form a hard, compact infusible material. The laminated sheet is a lightweight material that combines exceptional toughness and moisture resistance with excellent electrical properties.

Table 1—Properties of Laminated Plastics and Vulcanized Fiber

	Laminated Plastics (NEMA Grades)																						Vulcanized Fiber		
	X	P	PC	XX	XXP	XXX	XXXP	C	CE	L	LE	A	AA	N-1	G-1	G-3	G-5	G-6	G-7	G-8	G-10	GPO-1	Comm'l.	Bone	Elect. Ins.
General Information																									
Base material	Kraft paper	Paper	Paper	Paper	Paper	Paper	Paper	Cot fabric	Cot fabric	Cot fabric	Cot fabric	Asb paper	Asb fabric	Nylon cloth	Glass fabric	Glass fabric	Glass fabric	Glass fabric	Glass fabric	Glass mat	Glass cloth	Glass mat	Cot paper	Cot paper	Cot paper
Type of resin	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenol	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Phenolic	Melamine	Silicone	Silicone	Melamine	Epoxy	Polyester			
AIEE insulation class	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	H	H	B	B	B	A	A	A
Comparative price	0.7	0.8	0.8	1.0	1.0	1.1	1.2	1.4	1.4	1.7	1.7	1.1	2.7	3.7	2.9	2.7	2.4	6.7	6.7	1.8	3.7	0.9	.4	.4	.4
Electrical Properties																									
Dielectric strength perpendicular to laminations (G=500 v/mil for 1/16" mat'l.)	E	G	G	E	E	G	E	P	G	P	G	F	P	G	F	E	G	F	F	F	E	F	F	F	F
Dielectric strength, parallel to laminations (G=50 kv)	P	G	P	G	E	E	E	P	G	P	G	P	P	E	P	F	F	G	G	G	G	G	G	G	G
Dielectric losses	P	F	P	G	G	E	E	P	F	P	F	P	P	G	G	G	G	E	E	G	E	F	P	P	P
Insulation resistance	P	F	P	F	G	G	E	P	P	P	P	P	P	E	P	F	F	F	G	P	E	P	P	P	P
Arc resistance	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	E	E	E	E	F	G	E	E	E
Electrical stability (Humid conditions)	P	F	F	G	G	E	E	P	G	P	G	F	P	E	F	F	G	E	E	G	E	G	P	P	P
Mechanical Properties																									
Tensile strength (G=15,000 psi)	G	F	P	G	F	F	G	F	F	F	F	F	F	P	F	E	E	G	E	G	E	G	P	F	F
Flexural strength (G=20,000 psi)	G	F	P	F	F	F	G	G	G	G	G	G	G	F	E	E	E	G	E	G	E	G	P	F	P
Compressive strength (G=30,000 psi)	G	F	F	G	F	G	F	G	G	G	G	E	E	P	E	E	E	E	E	E	E	E	G	E	G
Impact strength (G=1.0 lb-ft)	G	F	F	F	F	F	F	G	G	G	G	G	G	G	E	E	E	E	E	E	E	E	G	G	E
Bond strength	G	F	P	G	F	G	F	E	E	E	E	F	E	G	G	G	E	G	P	E	E	G	G	G	G
Physical Properties																									
Water absorption	P	F	F	G	G	E	E	F	G	F	G	F	P	E	F	F	G	E	E	F	E	G	P	P	P
Dimensional stability (humid conditions)	P	F	F	G	G	E	E	F	G	F	G	F	P	E	F	F	G	E	E	F	E	G	P	P	P
Heat resistance	F	F	P	G	F	G	F	F	G	F	G	G	G	P	G	G	G	E	E	G	G	G	P	P	P
Chemical Properties																									
Acid resistance	F	F	F	F	F	G	G	F	G	F	G	F	F	G	F	F	P	G	G	F	G	G	P	P	P
Alkali resistance	P	P	P	P	P	P	P	P	P	P	F	P	P	F	P	P	G	G	G	G	G	F	P	P	P
Organic solvent resistance	F	P	P	G	F	E	F	G	G	G	G	G	G	G	G	G	G	P	P	G	G	G	E	E	E
Fabricating Properties																									
Machining qualities	F	F	F	G	G	G	G	E	E	E	E	F	F	E	P	P	P	P	P	P	P	P	E	E	E
Punching qualities	F	E	E	F	G	P	G	G	F	E	F	F	F	E	F	F	F	F	F	F	G	F	E	E	E

Code: E=Excellent, G=Good, F=Fair, P=Poor

Materials and Techniques for

Metal-to-Metal Adhesives

A DESIGN technique of rapidly growing importance is metal-to-metal adhesive bonding. High-strength phenolic elastomers, vinyl-phenolics and epoxy-resin adhesives are being used to an increasing extent for the structural joining of aluminum, brass, magnesium, steel, stainless steel, titanium and copper. High-strength adhesives allow the engineer to design stronger, more eye-appealing, more fatigue-resistant joints with thinner, lighter metals. In assemblies of thin sheets, the bond strength of the adhesive often exceeds that of the metal itself.

This article considers the factors involved in the selection of adhesives, the general types of adhesives available to the designer, and some important factors in structural bonding. It also gives design considerations by which adhesives can be employed most effectively in metal joints, and representative applications of the technique. Properties of adhesives are summarized in Table 1.

Selecting Adhesives

The important matter of selecting the right adhesive for each type of service is not a simple procedure. There is a great variety of adhesive products, and there is little standardization of their properties. Many users have resorted to writing their own performance specifications for procurement purposes. Others rely on specifications issued by government agencies. For most users, it is largely a process of evaluating several likely ad-

Table 1—Properties of Structural Adhesives

		Phenolic Elastomers	Vinyl Phenolics	Modified Epoxies: Room-Temperature Cured	Modified Epoxies: Heat Cured
	Room temperature	3000-4200 psi	2500-5000 psi	2500-4200 psi	3000-5000 psi
Shear	−65 F	3500-4500 psi	2000-3000 psi	350-2500 psi	1300-5000 psi
Strengths	180 F	1500-2800 psi	800-4000 psi	180-900 psi	2600-5000 psi
at	250 F	500-2500 psi	100-1800 psi	—	800-3600 psi
Various	300 F	400-2200 psi	100-1200 psi	—	450-3200 psi
Temperatures	350 F	300-1700 psi	100-500 psi	—	200-1200 psi
	Flexibility	Excellent	Fair	Poor	Poor
Physical	Room temperature creep and dead load strength	Good	Excellent	Excellent	Excellent
Properties	Elevated temperature creep and dead load strength	Good	Good to limiting temperature	Poor	Good to limiting temperature
	Peel strength	Excellent	Fair	Poor	Poor
	Water	Excellent	Excellent	Fair	Excellent
	100 per cent humidity	Excellent	Excellent	Fair	Excellent
Resistance	Salt spray	Excellent	Excellent	Poor	Excellent
to:	Oils	Excellent	Excellent	Excellent	Excellent
	Glycols	Excellent	Excellent	Good	Good
	Fuels	Excellent	Excellent	Excellent	Excellent
	Cure temperature	300-400 F	250-350 F	70-90 F	200-350 F
Curing	Cure pressure	25-200 psi	50-200 psi	Contact	Contact
Procedure	Cure time	30-240 minutes	30-120 minutes	1-7 days	60-90 minutes

Structural Bonding with

By Sydney A. Hanks, *Commercial Development Engineer*
Adhesives and Coatings Div.
Minnesota Mining & Manufacturing Co., Detroit

hesives against their known or projected requirements.

Applications should be studied to determine which properties and conditions are most important and limiting. In many cases two or more adhesives should be considered. Sample bonds should then be made and exposed to actual or simulated service conditions, and tested to determine actual bond strengths.

Parts to be bonded should be designed to take fullest advantage of the desired properties in selected adhesives. Adhesives seldom display their best properties when substituted directly for other fastenings. In the final selection of an adhesive, the engineer must consider end product properties, material costs, labor, capital expenditure for jigs and bonding equipment, and other factors which may affect the production and sale of products.

An adhesive joint derives its strength from using a larger contact area than joints of other types. Ideally, the whole joint is stressed if it is properly designed. Enough faying surface area must be designed into the joint to produce the required strength. If it is not possible to design for the best joint geometry, then an adhesive should be selected which performs best under the type of stress to be encountered. The adhesive that produces the strongest bond in tensile or shear will not necessarily produce the highest strength in peel.

In tensile or shear loading, the more rigid adhesive offers the greatest strength. However, if the joint will be required to flex or will be subjected to vibration or shock loads, then some compromise in ultimate strength must be made to provide a degree of resiliency to withstand the dynamic loading.

Peel-loaded joints are stronger when the adhesive has some elasticity. A brittle adhesive fractures readily and the joint fails progressively as stress is applied. Elastic adhesives are superior in peel because, in stretching under stress, they tend to widen the line along the load carrying edge. This distributes load over a greater area.

Greatly differing coefficients of expansion of dis-

Advantages of Adhesive Joints

1. Adhesives make it possible to join dissimilar metals with a minimum of bimetallic corrosion and also minimize corrosion from entrapment of moisture between surfaces. Adhesive acts as a continuous barrier between the two metals.
2. Continuous bonds produced by adhesives distribute stress loads evenly over entire joined areas. This eliminates local stress concentrations, produces joints of greater strength and rigidity than those made with separate fastenings and permits the use of lighter gage metals. These factors allow the design engineer to lower costs and weight and at the same time increase joint strength and rigidity.
3. Adhesive-bonded joints have good fatigue resistance. This is due to the stress distributing characteristics of adhesives and the ability of most adhesives to absorb or at least dampen vibration and shock. In many cases, adhesive-bonded metal joints have up to 10 times the fatigue resistance of riveted joints.
4. Adhesive bonding provides continuous contact between mating metal surfaces, thus sealing as well as bonding. This eliminates time and cost of separate sealing operations and permits the sealing of joints where it might not otherwise be possible. A good metal-to-metal bond is usually impervious to both liquids and gases. Many adhesives also act as electrical insulation.
5. Adhesive-joined metals form smooth, protrusion-free joints. This improves aerodynamics of exterior surfaces, enhances appearance, aids styling and eliminates gaps, bulges and external projections.
6. Adhesives maintain soundness of structural members. Holes for insertion of fasteners and countersinking to maintain a flush surface are unnecessary. Adhesives also eliminate excessive heat needed in welding or brazing operations that may tend to neutralize previous heat treatment.

similar metals can present a problem, particularly if the adhesive to be used is not sufficiently elastic. A brittle adhesive develops great internal stresses as changes in temperature occur. These stresses can become great enough to destroy the bond itself or cause warping in the assembly.

Some adhesives will take great loads of short duration, but fail progressively when stressed under conditions of dead loads. Such adhesives slowly creep when constantly stressed for long periods of time. Rigid adhesives are better for dead load conditions.

Service conditions also narrow the choice of adhesive. Service temperature range is one of these factors. Many metal-to-metal adhesives will perform at low temperatures in the vicinity of −65 F. At the other extreme, 180 F is a common limit. The modified epoxies and phenolic-elastomer adhesives maintain appreciable strength up to service temperatures of 350 F. Much work is being done today to force the limit upward to keep pace with advanced aircraft design. Some modified epoxy-resin and vinyl-phenolic adhesives have room temperature shear strengths up to 5000 psi, although 3500 psi is a more representative figure for commercially available products.

Exposure to solvents, chemicals, fuels and other deteriorating media are often a part of service requirements. Metal-to-metal adhesives with resistance to most solvents and chemicals are available. Resistance to all media cannot be found in any one adhesive. Some are completely inert;

Typical Structural Adhesive Applications

Honeycomb sandwich construction is an excellent example of new designs made possible through the use of adhesives. Sandwich construction consists of a lightweight core, sandwiched between two relatively tough, thin skins of metal. Cores consist of thin metal foils (or resin-reinforced paper or glass fabric), constructed in a cellular pattern resembling honeycomb. Such core constructions are sawed "across the grain" into sheets of desired thickness. Adhesives are used in the assembly of core materials and in the attachment of skins to the cores.

The light metals, aluminum and magnesium, can now be joined more strongly with adhesives than by any other method. The general advantages of adhesive joints apply particularly to light-metal joints in aircraft. In one case, helicopter blades had an average service life of 90 hours when assembled with rivets. Adoption of adhesive construction boosted the life expectancy to 1200 hours by improving the vibration resistance in the thin trailing edge of the blades.

Aircraft applications also take advantage of the excellent fatigue resistance of metal-to-metal adhesives. The importance of fatigue strength is recognized in Military Specification MIL-A-5090B which states that joints must remain intact after 10 million cycles under a fluctuating load from 0 to 600 psi. Several commercially available adhesives greatly exceed this figure today.

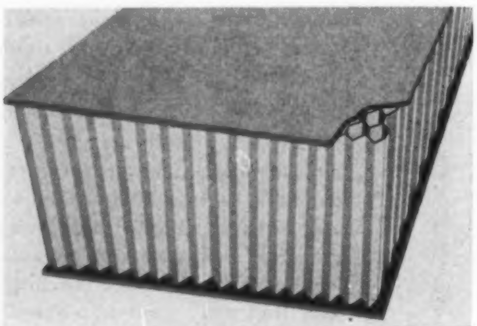
European aircraft manufacturers use metal-to-metal bonding adhesives extensively for attaching skin, making spars, webs and other heavy members more economically.

Phenolic-elastomeric resin type adhesives were used in the construction of B-36 wing panels. Some U.S. aircraft make use of adhesive bonding in load-carrying structures.

New elastomeric thermosetting adhesive films are used in bonding aluminum leading and trailing edges of helicopter rotor blades and are also used in bonding the trailing edges of aluminum aircraft wings. These adhesive films are also used in bonding aluminum to aluminum and the assembly of other metal-to-metal parts as primary and secondary structural components of aircraft missiles. Examples of such structures are compartment bulkheads, floors, skin, rudder and aileron members.

Phenolic elastomeric film adhesives are also used for structurally sealing integral aircraft fuel tanks and other closed systems.

Phenolic-elastomeric, vinyl-phenolics and epoxy



Honeycomb Sandwich Construction

Film Holder Has Adhesive-Joined Plates

and others are not affected seriously enough to impair their usefulness.

Types of High Strength Adhesives

Adhesives are not really new engineering developments. Animal, fish and vegetable glues, hydraulic-setting cements and natural asphaltums were used before recorded history. Adhesive progress, however, has been slow until very recent times because designs were such that adhesives carried little, if any, load. Also, at least one of the adherents was usually porous to allow escape of solvents.

Developments in the last few years in polymer chemistry and the commercialization of many new resins have greatly increased the selection of raw materials available for metal-to-metal adhesives. These new materials make it possible to formulate adhesives with load-bearing ability. By varying the selection of thermosetting and themoplastic resins, elastomers and fillers, adhesive properties of flexibility, heat and cold resistance, exposure resistance, shear strength, dead-load strength and peel strength can be greatly modified. Three general types of adhesives are commercially available today that will produce high-strength structural bonds. They are the phenolic-modified elastomers,

resin adhesives are used to seal and bond guided missile components—skin to stiffeners and fins, for example—wherever high bond strength in the 300-350 F range is needed.

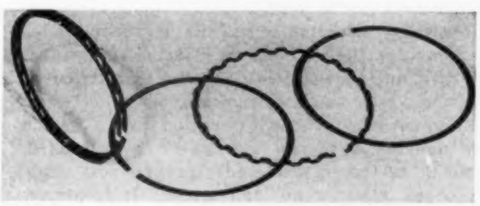
As rapidly as designs and tests can be completed, more aircraft structures and components will be joined and assembled with adhesives. As service history is accumulated, engineers are becoming more confident of adhesive-bonded structures.

An oil-resistant phenolic elastomeric adhesive provides a fast, easy method of joining anodized aluminum plates in a film holder at Graflex, Inc. The adhesive is sprayed on flat aluminum septum plates. The plates are then bonded to an aluminum core. The joining of the septums to the core was originally tried by spot welding but this method caused poor appearance and the aluminum was somewhat difficult to spot weld.

Metal-to-metal adhesives solved a problem at Muskegon Piston Ring Co. by allowing complex shapes to be fabricated that would probably be impossible with conventional methods. A spacer and two rails of oil rings are joined with a phenolic elastomeric rubber-based type adhesive to prevent separation during handling. In operation, the rings must separate into three component parts, each operating independently. When installed in an engine, the engine oil dissolves the adhesive, permitting the parts of the ring to perform unhindered. The adhesive is removed from the system with the first oil change.

One manufacturer uses an oil-resistant high-strength adhesive in the manufacture of automatic transmissions for motor busses. A carbon steel ring is joined by adhesive bonding to the machined surface of the torque converter housing. The adhesive also acts as a sealer against torque converter oil pressure. Operating temperature of the oil ranges from between 180 F to 220 F.

In the refrigeration industry, high-strength epoxy resin adhesives and phenolic modified elastomers are used to bond cooling coils to evaporators of home freezers. These adhesives are also used for bonding coils or tubing to fins of radiators used for dissipating heat.



Auto Engine Oil Rings: Components and Adhesive-Joined Assembly

Adhesive Sprayed on Film Holder Plates

Installation of Adhesive-Joined Oil Rings

the phenolic-modified vinyls and the epoxy-resin-based compounds. Each type offers certain advantages over the other two.

Phenolic-Modified Elastomers: High strength adhesives of the phenolic-modified-elastomer type have good adhesion to most metal and usually offer good flexibility, vibration absorption and peel strength. They have excellent resistance to fuels, lubricants, humidity and salt spray. This type adhesive is characterized by a rather flat, slowly descending curve, Fig. 1, when shear strength is plotted against service temperature. This type adhesive has a tendency to creep at elevated temperatures when subjected to dead loads that are in excess of about two-thirds of its shear strength. Room-temperature shear strengths are in the range of 3000 to 4200 psi in aluminum-to-aluminum joints.

Modified elastomers are particularly suited to the joining of thin metal sheets to themselves or to supporting structures. They are excellent for bonding and sealing integral fuel tanks and other liquid reservoirs. They may be used in honeycomb construction if a special effort is made to physically form a fillet between the honeycomb and the skin. Modified elastomers do not self-fillet. Phenolic-elastomeric adhesives are available in solvent

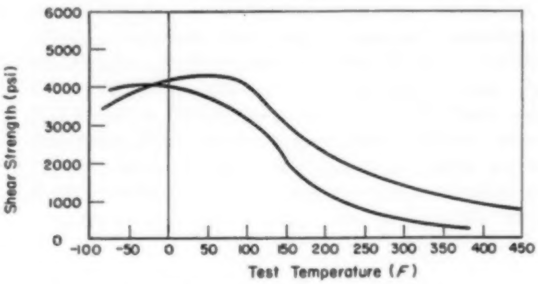


Fig. 1—Variation of shear strength with temperature of nitrile phenolic adhesive bonds between 2024-T3 Alclad aluminum sheets.

Designing for Metal-to-Metal Bonding Adhesives

Greatest strength is obtained in a metal-to-metal adhesive joint if the maximum amount of bonded area is put to work. The first fundamental of design for adhesive use is to plan all metal joints so that the geometry is most favorable to maximum strength.

In a joint loaded entirely in tension, the forces are in a direction perpendicular to the plane of the joint. The tensile force is distributed uniformly over the entire area. The entire joint is under stress at the same moment and all of the adhesive is at work at one time. It is a simple matter to calculate the load carried by any particular area in the joint.

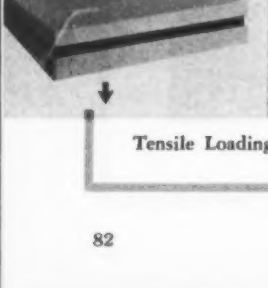
A similar situation exists in the shear loaded joint, except that the stress direction is parallel to the plane of the joint. Stress is distributed uniformly over the entire joint.

A somewhat different situation exists in the cleavage loaded joint. As the force is applied, one side of the joint is under great stress while the other is under no load at all. It is almost as if one side of the joint were hinged. Theoretically, the unit stress increases from zero on one side to infinity on the other. Therefore, not all of the adhesive in the joint is contributing its share of strength. The cleavage-loaded joint cannot be as strong as a joint of the same area under tensile or shear loading.

The least favorable situation of all, from the standpoint of strength, is the joint which is stressed in peel. In this case, even less of the adhesive contributes to strength than in the cleavage joint. All of the stress is concentrated along a fine line at the very edge of the joint. Most of the adhesive in the joint is under no load at all. This small portion of the total bonded area will support only a fraction of the load that the whole joint area could if the load were applied differently.

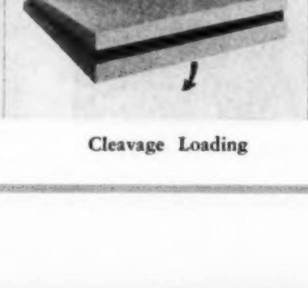
Rarely, if ever, is an ideal joint achieved in which the stresses are entirely pure tensile, shear, cleavage or peel. In practice, there is usually a combination of several different types of stresses and each joint must be carefully planned if maximum strength is an important factor.

Tensile Loading: In the case where metal joints are designed for tensile loading, two things can happen while the joint is under high stress. Either the forces do not stay in a direction perpendicular to the plane of the adherends, or one or both of the metal adherends, if thin, may tend to bend or twist. In either case, it is possible for the forces to resolve themselves into cleavage or even peel.



Tensile Loading

Shear Loading



Cleavage Loading

Peel Loading

solutions or as films.

Phenolic-elastomeric compounds are a one-part thermosetting resin and thermoplastic rubber-base type adhesive. Elastomers such as nitrile and neoprene rubber are modified by the addition of thermosetting resins to form load-bearing compounds. These compounds vary considerably from one to another depending on the type and amount of reinforcers contained in the formulation. The higher strength products usually contain vulcanizing agents for the rubbers as well as activators for the resins. Recommended curing procedure ranges from 300 to 400 F for 30 to 240 minutes under a pressure of 25 to 200 psi, depending on the adhesive used and properties required.

Modified Vinyl Phenolics: High-strength modified vinyl phenolics have good adhesion to most metals and offer good shear strengths at room temperatures. Shear strengths are in the range of 2500 to 5000 psi on aluminum. Strength drops off

rapidly as the thermoplastic temperature of the vinyl is approached, Fig. 2. This type adhesive has fair peel strength (superior to expoxies but poorer than phenolic-modified elastomers) and fair resistance to vibration and shock.

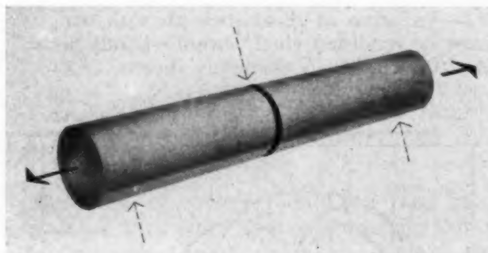
The modified vinyl phenolics have excellent resistance to water, 100 per cent humidity, salt spray, hydraulic fluid, engine oil and fuel. They have been used extensively in metal-to-metal honeycomb sandwich construction. Although they do not self-fillet, procedures have been worked out for applying the compounds to both honeycomb and faces, resulting in good honeycomb bonds. These compounds are available as solvent solutions or as supported films. Films offer the advantages of easy application, uniform thickness and reduced waste.

Vinyl resins such as polyvinyl-butyral and polyvinyl-formal are modified with phenolic resins to

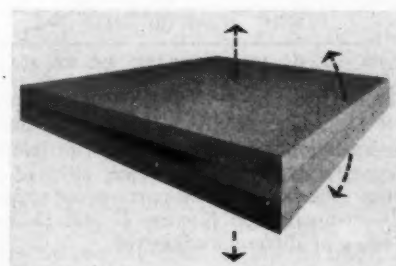
Adhesives do not lend themselves well to a butt joint design. In the case where two metal rods are butt joined with an adhesive, any bending of the rods can, through leverage, exert tremendous cleavage forces on the joint and can easily cause failure.

Tensile-loaded joints must be made with great care to insure uniform strength over the whole area. Any area of low strength, particularly if located near an edge, can induce a condition resembling cleavage and invite rapid failure.

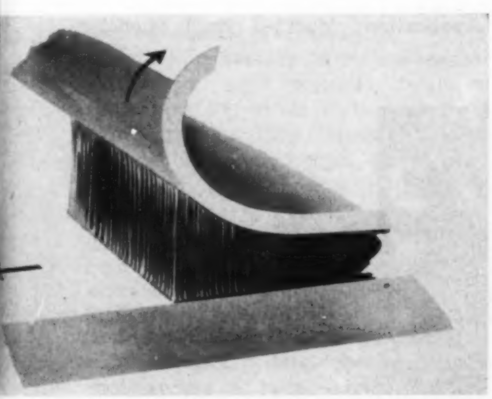
Shear Loading: The forces acting on a shear-loaded joint are not simple. If the metal adherends are completely rigid, an element of cleavage is induced as stress is applied. If the metal adherends are thin enough, they will bend slightly under load until the adhesive bond alignment is in better conformance with the direction of pull. As the stress is increased the metal deforms. The edges are then subjected to some peel stress and are more susceptible to failure.



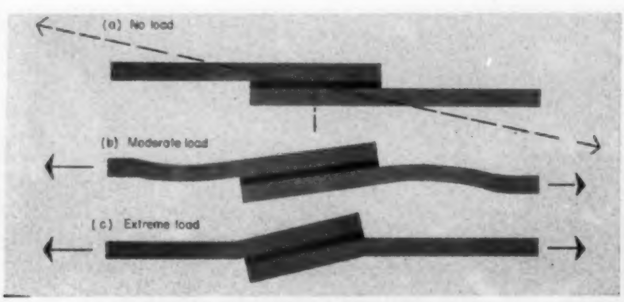
Forces Acting on Butt-Joined Rods



Effect of Weak Area in a Tensile-Loaded Joint



Detail of Peel Loading



Shear Bond under Increasing Load

form low-strength bonds by application of small amounts of heat and pressure. By increasing the cure time and temperature, the vinyls and phenolics can be made to crosslink and form new molecules with much higher heat resistance. Depending on the vinyl phenolic type adhesive used and properties required, curing ranges from 250 to 350 F for 30 to 120 minutes under a pressure of 50 to 200 psi are suggested.

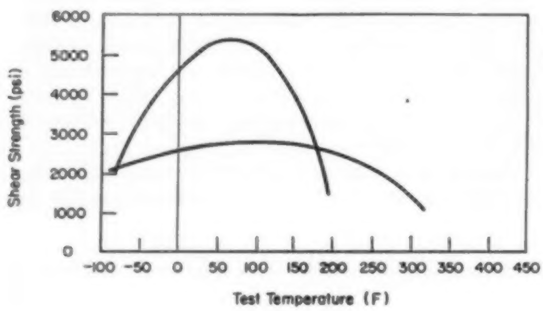


Fig. 2—Variation of shear strength with temperature of modified vinyl phenolic bonds between 2024-T3 Alclad aluminum sheets.

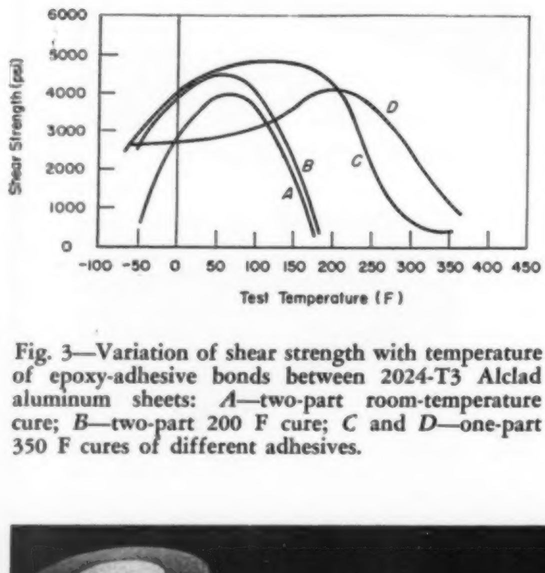


Fig. 3—Variation of shear strength with temperature of epoxy-adhesive bonds between 2024-T3 Alclad aluminum sheets: *A*—two-part room-temperature cure; *B*—two-part 200 F cure; *C* and *D*—one-part 350 F cures of different adhesives.

Epoxy Resin Adhesives: Most epoxy-resin adhesives offer a combination of high room-temperature strength with good load-bearing properties. These adhesives are usually quite brittle, have poor peel strength and some have poor shock resistance. They have excellent honeycomb filleting properties and exceptional adhesion to metal surfaces.

Most epoxy-resin based adhesives are two-part products (resin and activator) which when mixed together, will react and cure chemically even at room temperature.

Adhesives made from epoxy resins display a fairly uniform family of curves when shear strengths are plotted against service temperatures, Fig. 3. Each has a very definite temperature beyond which strength falls off rapidly. Room-temperature-cured specimens, usually cured with amines, lose strength very rapidly at 150 F and above. A 30-minute cure at 200 F raises the 180 F strength values considerably. To obtain strengths at elevated temperatures, epoxies are usually cured with acid anhydrides, diamides, dibasic acids, or phenolic resins at temperatures above 300 F. For applications where elevated-temperature resistance and resistance to salt spray and humidity are important, heat-curing epoxies should be carefully selected.

Factors in Structural Bonding

Cleaning: Proper cleaning of the metals to be bonded is one of the most important parts of bonding operations. The best adhesive will produce poor results when bonded to an unclean surface. In most cases, maximum results can only be attained when the surfaces are absolutely free of dirt, grease, oxides and other foreign materials. Surface coatings such as paints and primers, other than specific adhesive primers, can cause a weak link in metal to metal bonds. A degreasing operation followed by an acid etch or an electrolytic treatment is usually necessary to obtain best results.

Adhesive Application: Modified vinyl phenolic

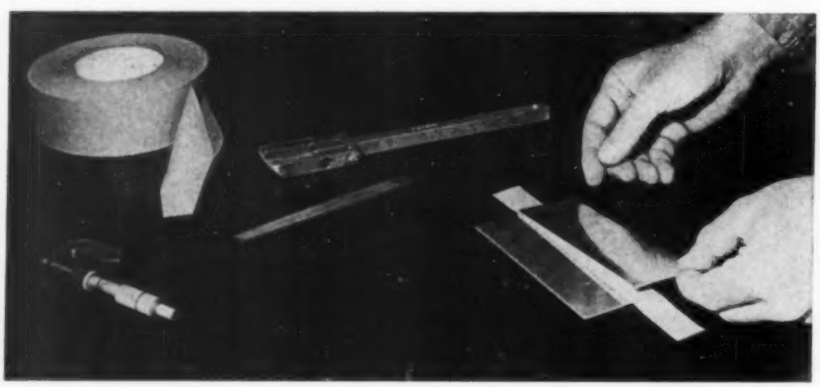


Fig. 4—High strength adhesive films are easily applied and have constant thickness. They are laid in place and bonded under heat and pressure.

and phenolic-elastomeric adhesives may be applied as films or as solutions. The epoxies are applied as 100 per cent nonvolatile liquids.

Adhesive films are usually laid in place either on the cleaned surface or over an adhesive primer that has been applied to the clean surface and thoroughly dried, Fig. 4. The 100 per cent nonvolatile liquids are usually knife-coated, brushed or applied with a notched trowel.

Solvent solutions may be brushed, sprayed, roll-coated or knife-coated. Solvents must then be allowed to evaporate completely before bonds are assembled. In some cases, force-dries at temperatures of 150 to 225 F are necessary to insure complete solvent removal.

Bonding: The use of structural adhesives may require jigs, fixtures, ovens, autoclaves or presses for assembling and proper application of heat and pressure during the curing cycle.

The bonding operation usually requires at least contact pressure, even during a room-temperature cure. Parts must be held in place while the adhesive sets. Pressures should be applied evenly to all parts of the bond area by jigs, fixtures or hydraulic or vacuum presses. Where heat and higher pressures are needed for curing, jigs and fixtures may be placed in ovens or autoclaves, or both heat and pressure may be applied through a heated press.

Personnel: The people connected with high-strength bonding must be conscientious, meticulous and have pride in their work. One smudge of dirt, a thumbprint, or one area where the adhesive has been improperly applied could be covered up in a bond and not show up until a part fails in use. Present methods of quality control of bonded parts depend on statistical analysis of results obtained from destruction testing. Such testing can only be accomplished on a percentage of the units produced. Until a satisfactory method of nondestructive testing has been developed, it will be impossible to completely evaluate each part. Quality is therefore controlled by the personnel who perform the application of the adhesives.

Tips and Techniques

Determining Gear Inertia

When computing moment of inertia of a gear in instrument applications, the formula for moment of inertia of a solid disk is usually used:

$$I = \frac{\pi \rho t D^4}{32}$$

where ρ = density of the material, t = face width and D = gear diameter. A plot of moment of inertia versus diameter for a given face width can be a useful aid to obtaining moment of inertia for gears of varying diameters. However, the curve is very steep because the fourth power of the diameter is involved and many points must be plotted to achieve accuracy.

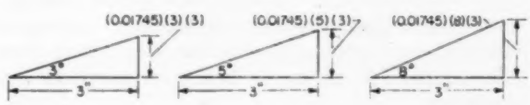
By taking the log of both sides of the equation and plotting log I versus log D, the curve becomes a straight line when plotted on log paper. Only two points are then necessary for each value of face width.— MAX FOGIEL, *New York, N. Y.*

Drawing Fillets and Radii

Correct radii for drawing fillets and other uses may be quickly determined using a triangle modified for this purpose. Using dividers, scribe a series of concentric circles on the triangle. Each circle should be $\frac{1}{8}$-in. larger in diameter than the one preceeding. When all circles are scribed, drill through the center hole using a drill of approximately 1/32-in. diam and countersink the hole. The circle of correct radius can then be quickly matched with other lines on a drawing and the center marked through the hole.—EUGENE GESSNER, *Towson, Md.*

Constructing Small Angles

Angles of 10 degrees or less may be constructed with very little error by employing the relationship that 1 degree = 0.01745-radian. To use this relationship, a line of fixed length such as 3 in. is first drawn. A perpendicular is then constructed at one end of this line. Length of the perpendicular should be 3 × 0.01745 × number of degrees, as shown by the sketches. A line joining the ends



of the two lines constructed is at the required angle with the first line. Error for angles less than 10 degrees is extremely small.—M. FEINSTEIN, *Westinghouse Electric Corp., Buffalo, N. Y.*

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Recommended methods of presenting
Maintenance Instructions

By John D. Folley Jr. and James W. Altman
Research Scientists
American Institute for Research
Pittsburgh

MAINTENANCE instructions that are hard to follow or not adequately presented are difficult to use and may even be avoided. Poor presentations also increase the chance of error in performing specified operations. Ineffective presentations can offset otherwise good design of equipment for maintainability.

Recommended types of data presentations that will serve various maintenance instruction functions are listed in Table 1.

Presentations of maintenance job information or instructions in paragraph form should be avoided. This format tends to obscure the step-by-step nature of procedures, and requires many words where other formats require few.

Information Content: Instructions should contain only information relevant to the job. Handbooks of maintenance instructions have frequently contained much information of very limited help to the technician in doing his job.

Instructions must be prepared specifically for each level of maintenance. One set of instructions should spell out the procedures for customer maintenance, another for the field, etc., rather than instructions for all levels being combined into a single set.

Nomenclature of code symbols used on the equipment should be used on job instructions. If a switch on the equipment is labeled PWR SW, the job instructions should refer to this control as PWR SW and not, for example, as "the master power switch." Where control labels on the equipment are particularly cryptic, the complete name of the control can be given in parentheses in the job instructions to clarify the label, for example, PWR SW (Master Power Switch).

Job instructions should present the required signal characteristics and tolerances for each test point. If signal characteristics are not given, the technician will have to figure out what the signal should be or, more likely, measure the signal on a properly functioning piece of equipment. If he cannot do either, the value of the procedure and the test point is lost.

Job instructions should be fully indexed. The index should contain words the technician is likely to look for in locating a particular item in the instructions.

Stock numbers needed for ordering replacement components should be presented with all parts lists.

All information in the instructions should be accurate. This seems almost too obvious to mention. Yet, technicians report that instruction manuals often contain errors. This suggests careful editing by the actual equipment designers or by persons familiar with the design of the equipment. Even a single error in job instructions may cause con-

Table 1—Recommended Data Presentations for Various Instruction Functions

Purpose of Data	Kind of Presentation
1. Describing procedures in detail	1. Step-by-step instructions
2. Describing procedures for experienced technicians	2. Check lists
3. Presenting physical features	3. Drawings and photographs
4. Presenting large amounts of data	4. Tables and charts
5. Describing processes or interrelationships	5. Diagrams

General recommendations are given here for presenting maintenance information and instructions in the most usable form for the maintenance technician. Suggestions are made on information content, physical characteristics, and revision and availability of instructions. Specific data are included on step-by-step instructions, check lists, drawings and photographs, charts and tables, maintenance diagrams, and signal data-flow diagrams.

This is the final article of a twelve-part series dealing with the design of electronic equipment for maintainability. Original material for this series was prepared, under Air Force contract, for the Psychology Branch, Aero Medical Laboratory, Wright Air Development Center, Dayton, O.

siderable wasted maintenance time and may even result in malfunctioning equipment being passed as operating in tolerance.

Physical Characteristics: Job instructions and diagrams that will be used continually will last longer if enclosed in plastic. This suggestion also permits the technician to make notes and erase what he has written after completion of the task, without damage to the materials.

Fold-out pages in manuals should be (1) kept to a minimum, (2) placed at rear of manuals, and (3) be readable with manual opened to another place by leaving blank the part of the sheet that is covered by other pages.

Table 2—Recommended Presentation of a Step-by-Step Job Instruction

Step No.	Component	Action	Indication[1]	Remarks
2.1	Antenna Assy.	Mount azimuth and elevation protractors		See Drawing P
2.2	Controls on pilots control box:	Set to:	Antenna travel on protractors is:	
	Operation Sw.	Auto-Search	Az: $\pm 23\frac{1}{2}°$	Adjust with
	Antenna-Az. Sw.	Center-Narrow		Pot. P2371
	Antenna-El. Con.	Center	El: $\pm 2\frac{1}{2}°$	Adjust with Pot. P2346
	Pulse Length Sw.	Long		
2.3	Antenna-Az Sw. Antenna-El Con.	Center-broad Full clockwise	Antenna travel on protractors is: Az: $\pm 67°$ El: $+30°$, $-25°$	Same as 2.1.1.2

[1]This is the particular aspect of equipment performance which the technician should note.

Customer-maintenance manuals should have maximum dimensions of no more than $5\frac{1}{2}$ by $8\frac{1}{2}$ in. and $1\frac{1}{2}$ in. thick so they will fit into a technician's coverall pocket. These manuals should be bound so that they will lie flat, and they should be printed in simple, straight type that has good readability under poor light, even for small type.

Printing of diagrams inside the covers of units is desirable if few modifications are anticipated. When modifications are made, correction sheets must be supplied to be pasted over the printed diagrams.

Attaching job instructions to auxiliary equipment is sometimes desirable. For example, a test set used only for aligning a particular computer could have a roll chart on the front panel that gives specific instructions for making the alignment. When roll charts are used for presenting procedures at least three steps of the procedure should be visible through the viewing window. This is particularly important when warnings may be included in various steps. The middle step should be emphasized by lines painted on the viewing window.

Revision and Availability: Job instructions should be kept current with modifications of the equipment. This is especially important when power voltages and/or signal characteristics change from one model to the next.

Whenever new models of an equipment are introduced, old job instructions should not be rescinded until all old models are withdrawn from use. However, job instructions definitely should be available for the new equipment.

Table 3—Check List Type of Instruction

Step No.	Action	Indication	Technician's Remarks
2.1	Mount protractors on antenna assembly		✓
2.2	Set controls for narrow scan center	Az: $\pm 23\frac{1}{2}°$ El: $\pm 2\frac{1}{2}°$	No vertical scan O.K.
2.3	Set controls for broad scan center	Az: $\pm 67°$ El: $+30°$ $-25°$	No vertical scan O.K.

Step-by-Step Job Instructions: This type of job instructions is well suited to maintenance tasks since it is set up for a sequence of steps. Each procedure can be divided into a series of steps and each step broken into a number of elements.

A format shown in Table 2 is strongly recommended for the presentation of procedural job instruction.

Check Lists: This less detailed form of instructions is especially useful to more experienced technicians. The division of procedural steps into elements is eliminated and the goal of each step presented as a reminder to the technician.

Customer technicians are quite likely to find checklists helpful because they often must work in places where detailed instructions are inconvenient to use. The designer should provide a standardized check list of instructions for customers, Table 3.

Drawings and Photographs: These two pictorial presentations of information can be very valuable for supplementing written job instructions. Generally speaking, good quality drawings will probably be at least as effective as photographs for this purpose. Photographs frequently show too much detail, thereby obscuring the particular item they are illustrating. On the other hand, photographs with irrelevant details blanked out and relevant details clearly shown can be very effective.

Drawings illustrating job instructions should include only the detail needed for the illustration. Extraneous detail in such drawings tends to obscure the point.

The purpose of including drawings in job instructions should be either to clarify written instructions or to provide information the technician needs for maintenance operations. Drawings inserted only for humor or aesthetic reasons probably add little to the value of the instructions.

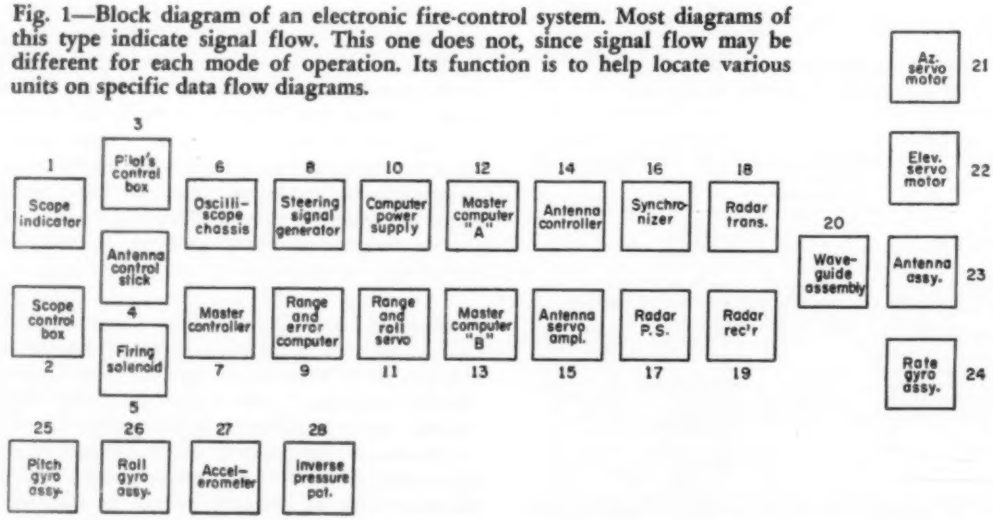
Tables and Charts: Tables are probably the most efficient way to present large amounts of data. Whenever similar information is to be presented concerning a number of different equipment components, tables may be particularly useful. For tables to be of maximum value, however, the maintenance job instructions should specify when and how each table should be used.

Information included in tables should be directly usable by the technician without his having to make any data transformations. Engineering test data, for example, are of little value to the technician. This same basic information translated into indications he should observe in the equipment may be indispensable to effective maintenance.

Maintenance Diagrams: The use of the term "diagram" is limited here to what may be loosely described as a map of either the physical features or functional interconnections of the equipment. Three types of diagrams are in common use:

Functional block diagrams usually suggest the general direction of signal flow from one major

Fig. 1—Block diagram of an electronic fire-control system. Most diagrams of this type indicate signal flow. This one does not, since signal flow may be different for each mode of operation. Its function is to help locate various units on specific data flow diagrams.



component of the system to another, Fig. 1. This type of diagram does not usually reflect the physical appearance or layout of the equipment.

Layout or wiring diagrams show the physical connection of equipment components with each other. Layout diagrams in particular reflect the actual physical structure of the equipment. Layout or wiring diagrams usually do not indicate either the direction or characteristics of signal flow.

Schematic diagrams show the electrical characteristics of components and the way in which the

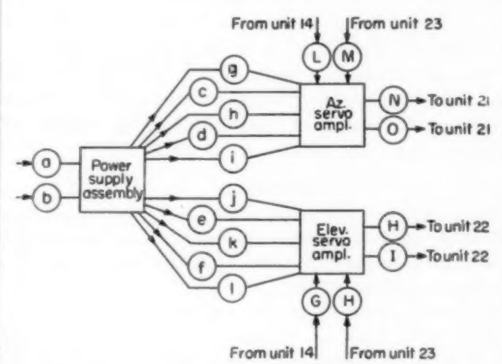


Fig. 2—Data-flow diagram for field-level technicians of unit 15 in the block diagram shown in Fig. 1. Chief function of diagram is to show signal flow between components. Tables of in-tolerance check readings, set-up of equipment, and recommended sequence of checks could be presented with this dia-

components are combined into circuits. They usually do not reflect the physical layout of the equipment or present the nature of signal flow among components.

Each of these types of diagrams can serve a useful function in the developmental sequence of a system. None, however, is specially prepared for use in maintenance operations, with the exception of a few equipment manufacturers' "loop books" or "servo diagrams."

The type of diagram which is quite useful to technicians is the data-flow diagram. This type of diagram includes features of each of the standard diagrams just discussed plus certain additional features.

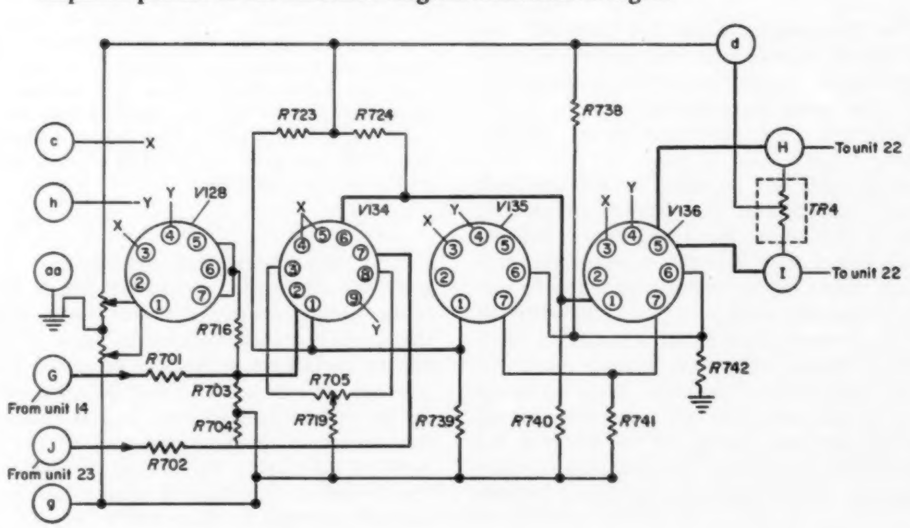
Maintenance diagrams should reflect equipment unitization. For example, the "building block" of the customer maintenance diagram should be the customer-replaceable unit. The value of unitized equipment will be severely reduced if this recommendation is not followed.

All of a particular circuit or loop should be on a single page insofar as possible. One exception occurs where trouble shooting is within a particular unit and the circuit runs from that unit to another unit and then returns. Then, it may be desirable to present on a single page only that portion of the circuit which is within the suspected unit.

Usually diagrams for customer technicians should be about 5½ by 8½ inches, since this size will fit easily into work-uniform pocket.

Facilities for using large diagrams, for example, 18 by 24 in., are usually adequate in the field or

Fig. 3—Data-flow diagram for field or factory-level technicians for elevator servo-amplifier portion of the data-flow diagram illustrated in Fig. 2.



Extra Copies

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in factories. Special stands or other provisions might make use of large-size diagrams more convenient.

Fold-over, map-board, and roll-chart types of stands are all convenient for large diagrams in the field and in factories. Diagrams on fold-over stands should probably be plastic coated to protect the diagram and to permit the technician to make notes that can be easily wiped off. A glass plate on the front of a roll chart will serve the same purpose. Diagrams on map-board type stands should be printed on a durable cloth-like material.

Diagrams similar to those just described should be used for all subsystems and units of equipment. It should be possible to trace signals from diagrams for one unit or subsystem to diagrams for another unit or subsystem. Where signals are shown leaving a page, the component of the equipment to which it goes should be indicated. The page on which the signal can be picked up again for tracing should also be given.

A table of contents and index of diagrams should be given. Color may be used to advantage on diagrams to code test points, types of signal flow, and classes of components.

Data-Flow Diagrams: These are prepared specially for use in maintenance and contain only information needed to perform specified maintenance activities. Components are shown in the same relative position as in the equipment so far as this is practical.

Components are not pictured or schematized; only enough information is presented to identify them, Fig. 2. Chief emphasis is given to the nature of the signal flow between components, particularly at points where "power on" checks can be made. Data-flow diagrams deal only with the electrical characteristics of the signal, not with the electrical characteristics of components.

Flow of fixed-voltage supplies to components may be indicated in special color or even omitted from the diagram completely. If the latter is the case, information concerning these voltage supplies may be presented on a separate diagram or in table form.

The appearance of data-flow diagrams is similar whether they deal with data flow among major units, assemblies, or subassemblies. A diagram of signal flow among parts may look like a combination of a schematic and a wiring diagram, Fig. 3.

Data-flow diagrams are based on a particular configuration of control settings for the prime equipment and/or test equipment. They may also be based on certain manually induced special conditions, such as broken feedback loops or servos set to a particular position. The control settings and special conditions are indicated on the diagram.

The electrical characteristics of the signal to be checked at each test point is shown on the data-flow diagram. When it is necessary to check complex time and shape characteristics of the signal, the required information can be keyed to tables at the edge of the diagram or to separate pages.

No information is given about the nature of signal flow within units that are replaceable or throw-away at the level of maintenance for which the diagram was prepared.

BIBLIOGRAPHY

This article is the twelfth and last in a co-ordinated series by John D. Folley Jr. and James W. Altman. Previous articles, and issues of MACHINE DESIGN in which they appeared are:

Designing Electronic Equipment for Maintainability	June 14, 1956
Units, Assemblies and Subassemblies	June 28, 1956
Covers and Cases	July 12, 1956
Wiring, Cables and Connectors	July 26, 1956
Maintenance Accesses	Aug. 9, 1956
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Displays	Oct. 4, 1956
Equipment Installation	Oct. 18, 1956
Maintenance Auxiliaries	Nov. 15, 1956
Maintenance Procedures	Dec. 13, 1956

Static Electrical Controls

In the article by John C. Ponstingl on "Static Electrical Controls," November 29, 1956, three of the typical curves in Table 3 on Page 97 were incorrectly located. The third curve from the bottom should appear with the phototransistor, the fourth curve from the bottom with the transistor, and the fifth curve from the bottom with the cadmium-sulfide and lead-sulfide photocells.

In Figs. 13*a* and *b*, the letter designations on the terminals of actuator coils should be the same as the coil designations.

" . . . the American design engineer, in contrast with his European competitor, tends to restrain those design features that adversely affect cost if the quality gained thereby is small. This is not due to variations between engineering teaching in America as compared to Europe (the subject matter is amazingly identical) but is fundamental to the American designer because of his American habit of measuring everything in terms of money. The result of this sort of design is a tremendous over-all savings in labor and in costs."—WILLIAM A. HADLEY, *director, Research and Engineering Div., Mergenthaler Linotype Co., Brooklyn, N. Y.*

Angular Relationships of a

Geneva Mechanism

During Indexing Movement

MACHINE DESIGN
Data Sheet

By Sol Dudnick,
Mechanical Design Engineer
Maryland Cup Company
Baltimore, Md.

THE Geneva mechanism is widely used for accurate intermittent or partial rotation of a driven shaft. Frequently in the application of such drives it is necessary to have work performed during the indexing portion of the cycle. In such cases it is usually necessary to know the exact instantaneous position of the driven gear for any position assumed by the driving gear. Presented here are the various formulas for determining this relationship. Also included are plots for various numbers of stations showing characteristic displacement curves.

Example 1: Assume that the position of the driven gear in a 6-station Geneva is desired when the position of the driving gear $\alpha = 42$ degrees.

From Table 2 for $n = 6$, $a/r_1 = 2$. For $\alpha = 42$ deg, $\sin \alpha = 0.6691$ and $\cos \alpha = 0.7431$. Then with

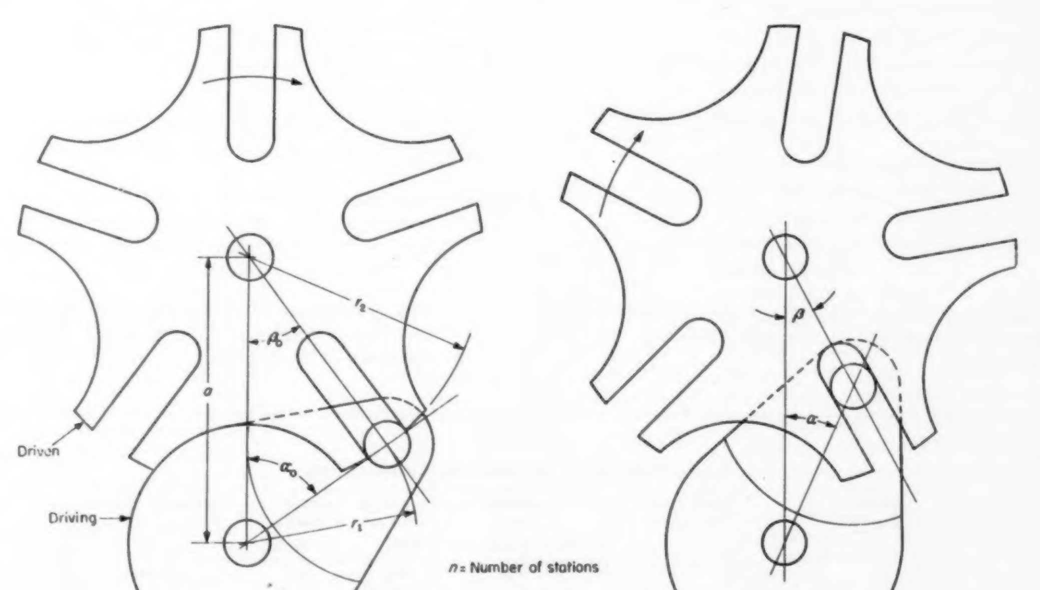

Fig. 1—Geneva mechanism in the position at commencement of motion, *a*, and a general position during indexing motion, *b*.

Geneva Mechanisms

Table 1—Equations

	Driving	Driven
Half-Angle	$\alpha_0 = 90 - \beta_0$	$\beta_0 = \dfrac{180}{n}$
Angular Position	$r_1 = a \sin \beta_0$	$r_2 = a \cos \beta_0$
Radius	$\alpha = 180 - (\beta + \gamma)$ $\sin \gamma = \dfrac{a}{r_1} \sin \beta$	$\tan \beta = \dfrac{\sin \alpha}{\dfrac{a}{r_1} - \cos \alpha}$

the equation for angular position of driven gear from Table 1,

$$\tan \beta = \frac{0.6691}{2 - 0.7431} = 0.5323$$

$$\beta = 28° \; 1' \, 40''$$

Example 2: If a number of closely spaced locations are desired, a graph may be plotted from several computed values and intermediate points found by interpolation. Assume from Example 1 that the location of the driven gear is desired when the driving gear is within the range of 41 to 43 degrees from the center line. From the method used in Example 1, the values of β are determined as:

$$\text{when} \quad \begin{aligned} \alpha &= 41, \beta = 27° \; 47' \; 0'' \\ \alpha &= 42, \beta = 28° \; 1' \, 40'' \\ \alpha &= 43, \beta = 28° \; 15' \, 45'' \end{aligned}$$

These values are plotted in Fig. 3. Intermediate values may be determined quite accurately without further computations. For example, when α is 41 deg 45 min, β is read directly as 27 deg 57.7 min. More information on Geneva mechanisms may be found in an article by Otto Lichtwitz—"Mechanisms for Intermittent Motion," Part 1, MACHINE DESIGN, December, 1951, Pages 134-148.

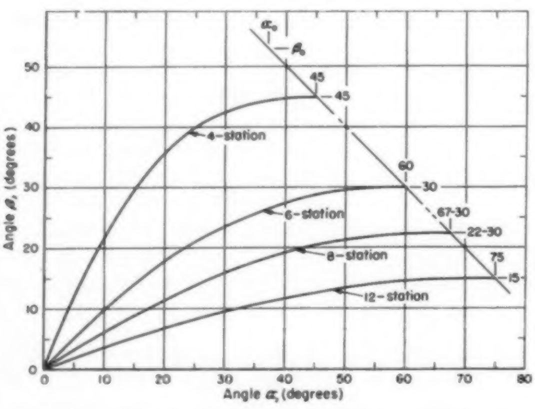

Fig. 2—Angular locations of driving and driven gears from centerline through half-angle of contact range.

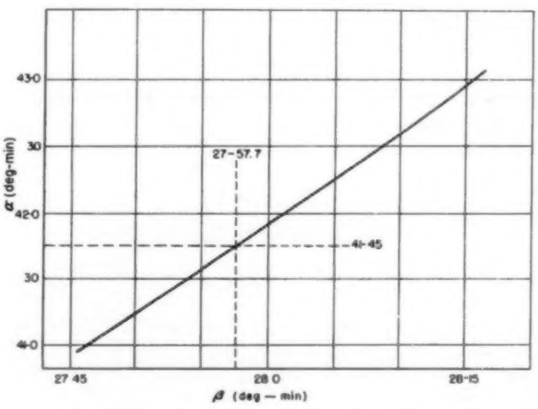

Fig. 3—Partial curve for determining values of β in a 6-station Geneva when α ranges from 41 to 43 degrees.

Table 2—Values of Geneva Relationships

Number of Stations n	Half-Angle (deg-min) α_0	β_0	Angular Ratio α_0/β_0	Ratio of Center Distance to Radius a/r_1	a/r_2	Duration of Motion Driving : Driven $(\alpha_0/\beta_0)/n$
3	30	60	0.5	1.1547	2	1:0.1667
4	45	45	1	1.4142	1.4142	1:0.25
5	54	36	1.5	1.7013	1.2361	1:0.3
6	60	30	2	2	1.1547	1:0.3333
7	64–17.14	25–42.86	2.5	2.3047	1.1099	1:0.3571
8	67–30	22–30	3	2.6131	1.0824	1:0.375
9	70	20	3.5	2.9238	1.0642	1:0.3889
10	72	18	4	3.2362	1.0514	1:0.4
12	75	15	5	3.8637	1.0353	1:0.4167

DESIGN ABSTRACTS

Selecting methods for

Filing Engineering Drawings

By Lester Gerber
Project Director
National Records Management Council Inc.
New York

IN THIS discussion, the term "engineering drawings" is used to include tracings, blueprints, and similar material. Four major types of equipment are available for filing these drawings: horizontal or flat files, hanging files, vertical files, and roll files. These four major types are manufactured in different sizes to correspond with the varying sizes of engineering drawings.

The following descriptions are a representative selection of each type of equipment:

1. HORIZONTAL OR FLAT FILES. Ten-drawer unit; approximate size—43 in. wide, 28 in. deep, and 41 in. high; drawers 2½ in. high.

2. HANGING FILES. Closed metal cabinet, fitted with hangers; approximate size—36 in. wide, 39 in. deep, and 72 in. high. (This type of file is also made as an open unit with a metal or wood frame.)

3. VERTICAL FILES. Vertical file with access from the top, fitted with pockets and compressor springs; approximate size—43 in. wide, 30 in. deep, and 36 in. high. Three, four, and five-drawer vertical filing cabinets are also available.

4. ROLL FILES. Closed metal cabinet with filing bins designed to hold 112 open fiber tubes vertically. The tube unit is permanently fixed and tilts forward. Variations of roll files are pigeon holes and open shelving units designed to hold drawings horizontally with and without tubes.

Evaluation Factors: There are six basic factors essential to judging the desirability of equipment:

1. Cost
2. Accessibility
3. Protection against wear and tear
4. Protection from environment
5. Security
6. Space utilization

Cost considerations involve two factors:

1. Average purchase price for standard units of equipment.
2. Cost per year of filing one drawing, reflecting both purchase price and space utilization. This is a summary figure calculated from initial purchase price, capacity and square footage occupied by the unit. The annual cost figure is the cost of equipment to house one drawing plus the cost of the floor space occupied by the equipment, Table 1.

Table 1—Cost Ratings for Filing Equipment

Annual Cost per Drawing (dollars)	Cost Rating
0.12 or more	Very high
0.10-0.12	High
0.075-0.10	Moderately high
0.035-0.075	Moderate
0.025-0.035	Low
0.025 or less	Very low

Accessibility means ease of filing, finding, removing and returning a drawing to the unit.

Protection against wear and tear is the protection provided by the equipment against a drawing being torn, wrinkled, cracked, smudged, etc., either accidentally or in the course of normal filing and finding.

Protection from environment is the protection provided by the equipment against a drawing being damaged by dust, dirt, grime, moisture, etc.

Security involves the protection provided by the equipment itself against unauthorized or chance scrutiny of a drawing in the course of normal operation without the aid of additional safeguards.

Space utilization is reflected by the following three measures:

1. Capacity: The number of active drawings that may be filed in one standard unit.
2. Drawing capacity per square foot of space: Equipment capacity to floor area occupied is determined by dividing the capacity of a standard unit by the number of square feet of floor space. The higher the resulting figure, the better.
3. Drawing capacity per cubic

Table 2—Summary Comparison of Filing Equipment

Equipment	Cost (dollars) Purchase Price	Cost (dollars) Per Year For Filing One Drawing: Active	Cost (dollars) Per Year For Filing One Drawing: Inactive	Accessibility	Protection against Wear and Tear	Protection from Environment	Security	Space Utilization (number of drawings) Per Unit: Active	Per Unit: Inactive	Per Square Foot: Active	Per Square Foot: Inactive	Per Cubic Foot: Active	Per Cubic Foot: Inactive
Horizontal or Flat Files													
Drawers 2½" high	300	0.061	0.046	Fair to Good	Fair to Good	Excellent	Excellent	1500	2000	80	100	23	30
Drawers 1" high	185	0.127	0.095	Good	Fair to Good	Excellent	Excellent	660	880	35	47	20	27
Hanging Files													
Closed metal cabinet with hangers	150	0.021	0.016	Good	Fair to Good	Good	Good	4000	5000	210	265	35	44
Open metal frame with hangers	100	0.078	0.067	Excellent	Fair	Poor	Poor	1300	1500	54	63	11	13
Open wooden racks	50	0.152	0.115	Good	Fair	Poor	Poor	750	1000	27	36	8	10
Vertical Files													
Access from top, pockets and compressors	410	0.028	0.021	Good	Good	Excellent	Good	3000	4000	185	250	62	84
Filing cabinet, 3-drawer, pockets and compressors	340	0.035	0.026	Very Good	Very Good	Very Good	Excellent	1500	2000	165	225	39	52
Filing cabinet 5-drawer follower-block	110	0.030	0.024	Very Good	Good	Good	Very Good	4000	1250	165	210	35	43
Roll Files													
Closed metal cabinet, bin, tubes	190	0.129	0.103	Fair	Fair to Good	Very Good	Very Good	400	500	38	47	6	7
Pigeon holes	150	0.123	0.074	Fair to Good	Fair to Good	Fair to Good	Fair to Good	600	1000	37	60	6	10
Open shelving, closed tubes	150	0.037	0.025	Fair	Fair to Good	Excellent	Good	2000	3000	120	180	17	26
Open shelving	50	0.069	0.046	Fair	Fair	Poor	Poor	1000	1500	60	90	10	15

foot: Since this figure includes height, it is valuable in judging those units of equipment that can be stacked one on the other within the same space. The drawing capacity is determined by dividing the capacity of a standard unit by the number of cubic feet utilized by the unit.

Ranking of Factors: The six factors just described are not of equal importance. To decide the order in which to rank these factors, the National Records Management Council weighed the comments of engineers, draftsmen, file supervisors and equipment manufacturers, and then measured them against the Council's experience in the actual installation of records control.

For active filing in the office, the consensus ranks the evaluation factors in the following order:

1. Accessibility
2. Space utilization
3. Protection against wear and tear
4. Cost
5. Protection from environment
6. Security

For inactive or semiactive filing in records storage, the factors were rated as follows:

1. Space utilization
2. Cost
3. Accessibility
4. Protection from environment
5. Protection against wear and tear
6. Security

These rankings are by no means to be considered hard and fast. Each person responsible for the filing of engineering drawings must determine for his own organization the importance of the six factors and evaluate equipment accordingly.

Analysis of Equipment: The available equipment may be analyzed by applying the six evaluation factors. Table 2 summarizes the findings and ratings of various types of equipment.

In using the table, it is essential that the ratings for one factor be balanced against those for the other factors. For example, the only type of equipment rated "excellent" on accessibility is rated "poor" as to security. If the draw-

ings are not classified information, the poor security is insignificant. By the same token, the high accessibility rating makes this same equipment most desirable for material frequently referred to. However, if security is a prime consideration, either another type of equipment should be selected or the entire filing area should be protected by using bars, vault doors or other safeguards.

In judging the cost factor, the initial purchase price should be considered in conjunction with the annual cost of filing a drawing. Some equipment is comparatively inexpensive to purchase or construct, but the annual cost of filing a drawing may run quite high. The cost element also must be balanced against the other factors. For example, the equipment that rates "excellent" on accessibility rates "moderate to moderately high" on summary cost. It must be reiterated that the final decision should rest with the individual organization after it applies to its own operations the six basic criteria.

Rating Equipment: In order to plot the six rating factors visually, the Council has developed a rating scale. The rating scale permits a quick comparison of the six rating factors in relation to the individual needs. The procedure is as follows:

STEP 1: Rank the six rating factors—accessibility, cost per drawing per year, protection from environment, protection against wear and tear, and security, in order of their importance. In the examples illustrated later, accessibility was ranked first, protection against wear and tear ranked second, while security ranked last.

STEP 2: Prepare a chart. In the left-hand column list the factors in their order of importance. In column two, opposite each factor post numerical factors in order of rank; Table 3.

Table 3

Factor ranked	Is weighted by
First	6
Second	4
Third	3
Fourth	2
Fifth	1

Thus, accessibility in our example has a weight of six points, while security is rated at one point.

STEP 3: At the top of the chart list the three additional column headings: Rating, Points, and Score.

STEP 4: Mark down in the rating column the evaluation of each factor for the specific equipment being rated. For example, for the vertical file with accessibility from the top, "accessibility" is rated as "good." Write "good" opposite accessibility. Continue the procedure until each factor is given its adjective rating.

STEP 5: Mark down in the point column the point values assigned to each factor in accordance with the rating shown in Table 4. For example, the "good" rating for accessibility to the vertical file is worth 4 points, the "excellent" rating for protection against wear and tear is worth 6 points, and so on. The one variation from this procedure is in rating the "cost" factor. This factor is rated by cost per drawing per year, Table 5.

Table 4

When factor is rated	Score points as
Poor	0
Fair	2
Good	4
Very good	5
Excellent	6

Table 5

When cost per drawing is (cents)	Equipment cost is rated	Score points as
Over 12	Very high	0
10-11.9	High	2
7.5-9.9	Moderately high	4
3.5-7.4	Moderate	6
2.5-3.4	Low	8
Under 2.5	Very low	10

STEP 6: Multiply the weight factor in column two by the points given to each rating. This gives the combination of how important each factor is (by order of rank) and how well the equipment rates on each factor.

STEP 7: Total the number of points. The higher the point score, the better the equipment will meet individual needs. The completed chart is shown in Table 6.

Table 6

Factor	Weight	Rating	Points	Score
Accessibility	6	Good	4	24
Protection against wear and tear	4	Good	4	16
Costs (per drawing per year)	3	Low	8	24
Protection from environment	2	Excellent	6	12
Security	1	Good	4	4
		Total	....	80

Conclusions: The many types of equipment currently available satisfy most needs and preferences. On the basis of the study completed by the National Records Management Council, the following conclusions may be drawn:

1. Each individual must, in the final analysis, rate the equipment for his own particular set of conditions and preferences. The rating scale can only be used as a guide to those faced with the problem of selecting storage equipment for engineering drawings.

2. For active filing in an office area, hanging or vertical units are preferable. Both rate well with respect to accessibility and are marked by low annual cost for filing drawings. Filing cabinets with access from the front are well suited to smaller drawings. The drawings are accessible and protected. The cost per drawing per year is low when small drawings are filed.

3. For inactive filing, those units that can be stacked provide good value. The use of open shelving and closed tubes offers good protection and security at a low annual cost per drawing. The disadvantages of a possible accident hazard with stacked units, and of indexing with shelving units can be more than offset by the savings in cost. Reasonable precautionary measures and improvisations to meet individual conditions can be instituted at reasonable costs and little work.

4. Very long drawings (over 48 in. long) are best filed in files which provide an effective combination of maximum protection, accessibility and reasonable cost.

From a paper entitled "Standards for Filing Engineering Drawings" presented at the ASME Annual Meeting in New York, November, 1956.

Flame-Sprayed Ceramic Coatings

for high-temperature applications

By A. P. Shepard
Chief Development Engineer
Metallizing Engineering Co. Inc.
Westbury, L. I., N. Y.

ALUMINA and zirconia are ceramics well adapted to flame spraying. They have low thermal expansion coefficients as compared to most metals and alloys. This characteristic is essential where coatings must function as thermal barriers, as on parts which receive some cooling influence on the side opposite the coating.

There are two reasons why the coefficient of expansion of the coating material must be low. First, a sharp thermal gradient exists within the coating itself, and a high expansion coefficient would set up stresses which would cause the coating to disintegrate. Second, the mean temperature of the coating will be much higher than that of the metal to which it is applied, so the coating must have a low expansion coefficient to reduce stresses between coating and metal.

Ideally, where a thermal gradient exists, a gradient in the expansion coefficient should exist. Composite ceramic coatings, formed by applying zirconia over alumina, or alumina over zirconia, are a step in this direction.

Advantages: Several advantages are apparent for thermal barriers of this type, applied to jet engine combustion chambers or rocket nozzles for example. First, the high hardness and high melting temperature of the ceramic provides resistance to surface deterioration. Second, the operating temperature of the metal shell is reduced, permitting equivalent strength with thinner sections. Third, the need for superalloys may be eliminated in some cases, because of lowered operating temperatures. Protection against oxidation may be provided with thin sprayed coatings of heat-resistant alloys beneath the ceramic coating or on the opposite side of the member if required. A fourth possible advantage may reside in increased thermal efficiency of the engine or rocket, since an incandescent ceramic skin would not be expected to cool the outer boundaries of the gas stream as would a much cooler metal surface.

Where the coating is not subjected to high temperatures, the resistance of flame-sprayed ceramics to impact and to abrasion may be greatly improved by impregnating. Phenolics, furanes, silicones, epoxy-based formulations, and a variety of other organic and inorganic impregnants have been used successfully. In general, those materials which show good physical properties should be used. For example, phenolics and furanes are excellent impregnants. The heat-cured types are preferred, because of superior physical properties, but good results have been obtained with catalyzed or air-dried types.

Some of the properties of alumina-base and zirconia-base coatings are shown in Table 1.

Applications: A number of practical applications for alumina-base coatings are:

1. Coating fan blades subject to abrasion. Fine particles of abrasive have no effect on alumina coatings. Heavy abrasion, as by sand blasting, will break down the coating by impact, but the effect of fine abrasives is negligible. Alumina coatings sealed with a baked or catalyzed phenolic are relatively impermeable and will withstand a great deal of mechanical abuse.

2. Special corrosion problems that may be solved by impregnating alumina coatings with an appropriate sealer. The alumina provides physical integrity and is completely inert to most chemicals. The sealer may be selected on the basis of resistance to the specific reagent involved, without the need of considering the physical properties of the sealer.

3. Gages, surface plates, instrument ways. Alumina coatings may be ground with diamond wheels, or even with silicon-carbide wheels, to produce a fairly smooth and very hard corrosion-resistant surface having a low friction coefficient. Impregnation with microcrystalline wax or other sealants may be used where corrosive conditions are severe. Solid lubricants such as molybdenum disulphide or graphite may be added to the impregnant for special bearing applications. Nearly all metals will run against such surfaces with very low friction and no tendency to gall.

4. Use on special-purpose bearings, processing rolls, filters, mixer or agitator parts, and a host of other possible applications which can be expected to develop with time. Even though somewhat porous (6 to 10 per cent), alumina coatings have a compressive strength in excess of 200,000 psi. Pores may be filled with an appropriate sealer, with a lubricant, or left unfilled as required.

5. Both alumina and zirconia coatings are completely resistant to nearly all molten metals, although some of the common fluxes (for example zinc-ammonium chloride) will penetrate the coating and attack the base.

From "Notes on Sprayed Ceramic Applications" in Metco News, *Vol. 8, No. 3, published by Metallizing Engineering Co. Inc.*

Table 1—Properties of Typical Alumina-Base and Zirconia-Base Coatings

Property	Alumina	Zirconia
Melting point (F)	3700	4600
Bulk density (g/cc)	3.2 to 3.4	5.2 to 5.3
Porosity (per cent)	6 to 10	6 to 10
Thermal expansion (per deg F $\times 10^{-6}$)	4.3	6.4
Hardness (Moh's scale)	9.0	8.0
Thermal conductivity* (Btu/hr/sq ft/in./deg F)	19	8
Deposition (sq ft/hr, 0.010-in. thick)	15	10
Color	Gray	Tan-Brown

*On this same scale 18-8 stainless steel would read 185 and carbon steel 320.

Circle 441 on page 19

HELPFUL LITERATURE

for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Aircraft Tube Fittings

"Aircraft Piping and Engineering Application Manual" deals with data on cluster fittings, installation and assembly methods, piping application categories, and engineering recommendations. Also presented is information on design, selection and installation of various aircraft piping systems. 44 pages. Weatherhead Co., Aviation Div.

Circle 501 on page 19

Hydraulic Systems

Hydraulic systems for turbo-jet and turboprop aircraft engines are discussed in bulletin A5211 entitled "Vickers Looks Ahead to the New Engines." High temperature tests of hydraulic components are described. Covered are hydraulic pumps, motors, controls, servos and starters. 8 pages. Vickers Inc.

Circle 502 on page 19

Metal Laminates

Company's new laminates are combinations of two or three metals permanently and metallurgically bonded together to form one "sandwich." Properties, applications, types, sizes and other engineering details are provided on these laminates in bulletin 10NE6. 8 pages. Bridgeport Brass Co.

Circle 503 on page 19

Die Cast Gears & Pinions

Spur and cup gears as well as pinions produced from stock dies are listed in data sheet. Combinations of gears, pinions, hubs and shafts can be made to specification at low cost. 2 pages. Gries Reproducer Corp.

Circle 504 on page 19

Hydraulic Tube Fittings

Design, dimension and ordering information on complete line of straight-thread fittings for hydraulic tubing is contained in catalog ST-56. Metal ring, captive nut and O-ring sealing types are included in styles for every purpose. 24 pages. L & L Mfg. Co.

Circle 505 on page 19

Photoelectronic Edge Control

Linar Edgetrol photoelectronic edge guidance system for the precise control of edge register of moving material is subject of two illustrated bulletins. Operation is by means of electric light beams, without force or pressure applied to material. 4 pages each. Intercontinental Dynamics Corp.

Circle 506 on page 19

Static Magnetic Controls

"Cypak Magnetic Control" is title of manual TD 52-760 which deals with magnetic controls and logic functions for industrial control. Discussed are basic "and," "or," "not," and "memory" logic functions; the circuitry providing these functions, including the basic Ramey magnetic amplifier circuit; and current applications to industrial control. 8 pages. Westinghouse Electric Corp.

Circle 507 on page 19

Heat Exchangers

Shell and tube heat exchangers for hydraulic equipment, diesel and gas engines, transformers, machine tools, coolants and processes in chemical, food and pharmaceutical fields are subject of illustrated catalog 1156. Selection and heat exchange data and formulas are included. 16 pages. Young Radiator Co.

Circle 508 on page 19

Filter-Regulator-Lubricator

Adaptable for air and some gas services, line of pressure regulators, lubricators and filters is offered for ¼ to ½-in. fluid lines. Also available are combinations of two or three of these units for pressures to 250 psi and 300°F. Full specifications are given in bulletin F-15A. Watts Regulator Co.

Circle 509 on page 19

Carbide Tools

Centers, boring bars, replacement tips, drills for hardened steel, diamond wheels, milling cutters, slitting saws and many other carbide tools are described in catalog No. 956. Over 700 tools are detailed. 50 pages. Nelco Tool Co.

Circle 510 on page 19

Plastic Rods & Shapes

Physical properties, available sizes and typical applications for Plexiglas and Lucite acrylic rods, tubes and shapes which are stocked for immediate delivery are listed in illustrated bulletin. This clear plastic has "light piping" and other unusual optical properties. 4 pages. Ace Plastic Co.

Circle 511 on page 19

Instrument Components

Engineering data on components for use in the electronic and instrumentation fields are contained in catalog No. 11. Stock precision parts include shafts, gears, pins, assemblies, mounting plates, breadboard and differential kits, speed reducers, couplings and fasteners for use in servo, instrumentation and development work. 132 pages. PIC Design Corp.

Circle 512 on page 19

Detachable Sheaves

The "Fort Worth Standardized QB Sheave Specification Guide" lists 739 stock sizes of quick-detachable sheaves ranging in diameter from 3.4 in. to 6 ft. Data are given on sheaves for A and B, C and D-section V-belts. Ask for catalog section 83-A. 16 pages. Fort Worth Steel & Machinery Co.

Circle 513 on page 19

Subminiature Meters

Illustrated data sheet 230 describes a new line of 1-in. round flush-mounting panel meters which incorporate a miniaturized D'Arsonval movement. Accurate types are offered for indicating microamperes, milliamperes, millivolts and volts. 2 pages. International Instruments Inc.

Circle 514 on page 19

High Vacuum Pumps

"Stokes Microvac Pumps for High Vacuum" is a guide book to pump details which contains tables of formulas, constants and conversion factors relating to vacuum processing. Solutions are given to pump problems for typical vacuum systems. Applications for high vacuum processing are discussed. 28 pages. F. J. Stokes Corp.

Circle 515 on page 19

Static Control Elements

How static controls operate without moving parts and how they cover the logic function concept, as well as logic functions, circuit characteris-

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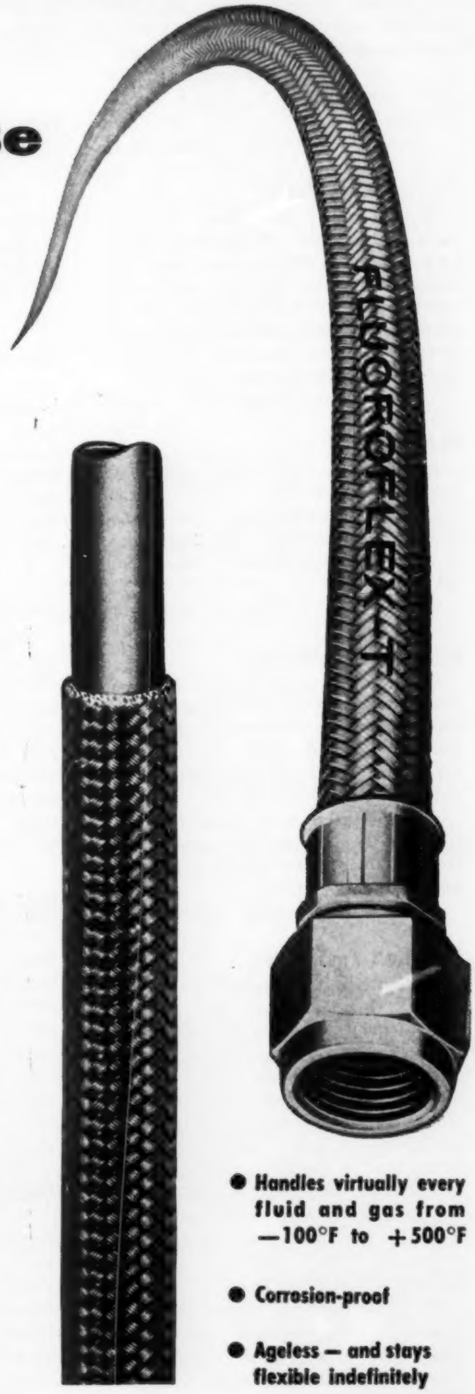

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Circle 442 on page 19

tics, monitor lights and amplifiers are discussed in bulletin GEA-6578. Fundamentals and features of general-purpose static control logic elements are covered. 8 pages. General Electric Co.

Circle 516 on page 19

Printing Calculator

In addition to describing the operation of the model 99 printing calculator, manual C1053 No. 9 explains procedures to be used in engineering departments for solving mathematical problems. Other office applications of this machine are covered. Sperry Rand Corp., Remington Rand Div.

Circle 517 on page 19

Greases

Applications and specifications of Prestige 40 series of premium greases are given in bulletin 50. This grease is suited for service involving water or high temperatures. 2 pages. Sun Oil Co.

Circle 518 on page 19

Synchronous Motors

Design and performance data on Synduction motors are given in bulletin 51B8440A. This synchronous induction machine provides constant speed for industrial applications requiring less than 40 hp. Variable speed operation is possible by using variable frequencies in speed range from 200 to 10,000 rpm. 4 pages. Allis-Chalmers Mfg. Co.

Circle 519 on page 19

Research Facilities

In addition to complete production plants, this company has facilities for research, development and testing of electronic, electro-mechanical, optical, data reduction and transmission, control and guidance, calibration, infrared, communication and navigation systems and components. Details of facilities are given in bulletin "Men and Machines". 4 pages. Servo Corp. of America.

Circle 520 on page 19

Silicon Transistors

Two production types of silicon transistors which meet the rigid requirements of Navy specifications are announced in bulletin DL-S 635. Performance characteristics are listed. 4 pages. Texas Instruments Inc.

Circle 521 on page 19

Sealed Miniature Switches

Catalog No. 5 is devoted to information on miniature hermetically-sealed switches for standard and special applications. This handy idea folder contains specifications, schematic drawings and application details. Haydon Switch Inc.

Circle 522 on page 19

Tube Cap Connectors

New tube cap connector designs for airborne and missile equipment as well as for electrical and electronic equipment tubes are described in illustrated guide book for electronic design engineers. 18 pages. Alden Products Co.

Circle 523 on page 19

Porcelain Insulators

Screw type wire holders, house brackets, spools, split and solid knobs, tubes, cleats, antenna and guy strain insulators, telephone knobs and pipe thread bushings are among the many porcelain insulators described in illustrated catalog. 8 pages. Universal Clay Products Co.

Circle 524 on page 19

Electric Motors

Condensed engineering and performance data on commonly used electric power drives are contained in condensed catalog. Prices and selection information are included on normal speed motors, geared motors, variable speed drives and speed reducers. Tables simplify drive selection. 20 pages. Sterling Electric Motors, Inc.

Circle 525 on page 19

Film Type Heaters

Solutions to difficult heating problems due to odd contour shapes, space or weight limitations are described in series of folders. Series points out advantages of Electrofilm sprayed-on film type heating elements which weigh 1/10-lb per sq ft and are 0.015-in. thick. Electrofilm, Inc.

Circle 526 on page 19

Flexible Metal Hose

Design suggestions for planning flexible metal connector applications are provided in catalog G-560 on flexible metal hose and tubing. Specifications, bend diameters, lengths, types, construction diagrams and descriptions of end fittings are included. Hose is offered in bronze, brass, steel, stainless, aluminum, Monel, nickel and plastics, 64 pages. American Brass Co., American Metal Hose Div.

Circle 527 on page 19

Screw Machine Products

Typical Allmetal screw machine work in a variety of alloys, including stainless steel, Inconel, nickel and titanium, is shown in new folder. Fabrication operations and techniques required for each of eight items are described along with dimensions and tolerances. 4-pages. Allmetal Screw Products Co.

Circle 528 on page 19

Freewheeling Clutches

Comprehensive manual covers automatic freewheeling clutches, combination clutch-couplings, backstops to prevent reversed runaway of inclined conveyors or vertical elevators, and enclosed freewheeling clutch units for continuous operation. Manual contains 110 large illustrations. 76 pages. Marland One-Way Clutch Co.

Circle 529 on page 19

Corrosion-Resistant Motors

Series 254-U All-Weather rerated motors descriptively covered in bulletin 520 feature special corrosion-resistant steel housing which affords protection against all adverse weather conditions. Integral metal and cast iron parts are also given an anticorrosion treatment. 8 pages. Robbins & Myers, Inc.

Circle 530 on page 19

Teflon Tape

Use of Temp-R-Tape, a pressure-sensitive Teflon tape, for Class H insulation and nonstick-facing is described in pocket-size folder. Tape is available in 0.006 and 0.013-in. thicknesses, ¼ to 12 in. wide, in rolls or on cloth backing. 4 pages. Connecticut Hard Rubber Co.

Circle 531 on page 19

Levelers

Bulletin 564 describes three types of levelers for movable office partitions, electronic and office equipment, air conditioners, display cases, appliances and process equipment. Featured style FB has thick neoprene pad for vibration absorption. 4 pages. Ohio Nut & Bolt Co.

Circle 532 on page 19

Embossed Metals

Nineteen embossed metal patterns are illustrated in folder along with maximum lengths and width information. 6 pages. Croname Inc., CroRoto Div.

Circle 533 on page 19

Stripped Pumps

Tuthill stripped pumps for built-in lubrication, hydraulic, coolant, liquid transfer and circulating service are subject of catalog 106. Pumps are rotary, internal-gear, positive dis-

Circle 443 on page 19

placement type and range in capacities up to 200 gpm at 0 psi. 12 pages. Tuthill Pump Co.

Circle 534 on page 19

Investment Casting

"Design—with Microcast in Mind" is title of brochure which outlines the steps involved in investment casting and shows the wide range of intricate parts that can be mass produced by this method. It includes the most recent table of properties of investment cast alloys. 12 pages. Austenal Laboratories, Inc., Microcast Div.

Circle 535 on page 19

Four-Way Air Valves

Three new models added to Allenair line of ¼, ⅜ and ½-in. four-way air valves are available as single solenoid, or foot or cam operated units. Valves operate on 5 to 150 psi. Solenoid units will reciprocate at 800 strokes per minute. Details are provided in well illustrated catalog V-103. 8 pages. A. K. Allen Co.

Circle 536 on page 19

Fluid System Specialties

Parker fluid system specialties shown in catalog 4395 include clips for support of tube lines, dual heat transfer coil for cooling applications, pressure snubber for protection of gages and manifold valve to simplify draft gage line blow out. 4 pages. Parker Appliance Co., Tube & Hose Fittings Div.

Circle 537 on page 19

Aircraft Hose Products

Engineering data pertaining to Aeroquip low, medium and high pressure hose assemblies with detachable, reusable fittings and self-sealing couplings, flange fittings and elbow assemblies are given in Aircraft Catalog 101. Latest medium-pressure Teflon hose is included. Aeroquip Corp.

Circle 538 on page 19

Fiber & Plastic Parts

Booklet "Fabricated Parts and Components . . . Management Decision for Profit" shows machining operations and parts made of vulcanized fiber and Phenolite laminated plastic. It points up economies of dealing with a single source for fabricated parts. 12 pages. National Vulcanized Fibre Co.

Circle 539 on page 19

Autotransformers

Portable, motor drive, enclosed and ball bearing models of the Variac continuously - adjustable autotransformer are cataloged in form 424-O. Duratrak contact surface applied by electroplating process using special silver alloy eliminates oxidation problems. 24 pages. General Radio Co.

Circle 540 on page 19

Plated Wire

Specifications and characteristics of Nickelply and Brassply electroplated steel wires are provided in bulletin K-10. Nickel and brass coating will not separate from base metal under severe twisting, forming or redrawing operations. 8 pages. National-Standard Co.

Circle 541 on page 19

Flexible Couplings

Torsionally flexible Morflex standard, double and radial couplings are described with complete dimensions and specifications in catalog C 41-56. Morflex principle employs preloaded rubber biscuits as flexible medium. 24 pages. Morse Chain Co., Industrial Sales Div.

Circle 542 on page 19

Motor Selection

Information on how to select alternating-current motors for .specific applications is given in motor selector bulletin B-2103-1. Data cover frame sizes from 182 to 6085. Glossary of motor enclosure terminology is included. 12 pages. Reliance Electric & Engineering Co.

Circle 543 on page 19

Hermetic Compressors

Field serviceable hermetic compressors for use in packaged chillers, air conditioners and commercial refrigeration units are subject of bulletin C-1100-B93 P. Available in 2 to 7½ hp sizes, compressors are machined of interchangeable precision parts. 4 pages. Worthington Corp.

Circle 544 on page 19

Screw Thread Inserts

Performance data, design relationships, installation procedure and standard size data on Heli-Coil screw thread inserts are included in illustrated bulletin 748. "Designing Your Product" contains design data and specifications for cutting costs. 4 pages. Heli-Coil Corp.

Circle 545 on page 19

Stampings & Deep Drawings

Design and ordering information on stampings and deep drawings is found in illustrated brochure. Some difficult design problems are shown, and materials, tooling, time requirements and operations are discussed. 6 pages. Stanley Works, Stanley Pressed Metal Div.

Circle 546 on page 19

Aircraft Heater Controls

Eight different configurations of aircraft heater controls and a rate-of-rise control are described in bulletin MC-131. Temperature range, current ratings, physical dimensions and mounting methods are covered. 4 pages. Fenwal Inc.

Circle 547 on page 19

Spring Design & Selection

Fundamentals of spring design are presented in sufficient detail to guide the designer through initial stages of a design problem in illustrated brochure "Spring Design and Selection—in Brief." Basic formulas, commonly used materials, typical applications and limitations are covered. 8 pages. Associated Spring Corp.

Circle 548 on page 19

Machinery Mounts

Elasto-Rib vibration and noise absorbing machinery mounts are described in illustrated bulletin K2D. Material properties and those of Universal Dampers incorporating the material are detailed. Capacity tables are included. 2 pages. Korfund Co.

Circle 549 on page 19

Shell Molding Resins

"Plaskon Resins for Shell Molding" is illustrated booklet which describes the process, design and production considerations, available types of molding machinery, production techniques, special metals handling and sand reclamation, among other subjects. 32 pages. Allied Chemical & Dye Corp., Barrett Div.

Circle 550 on page 19

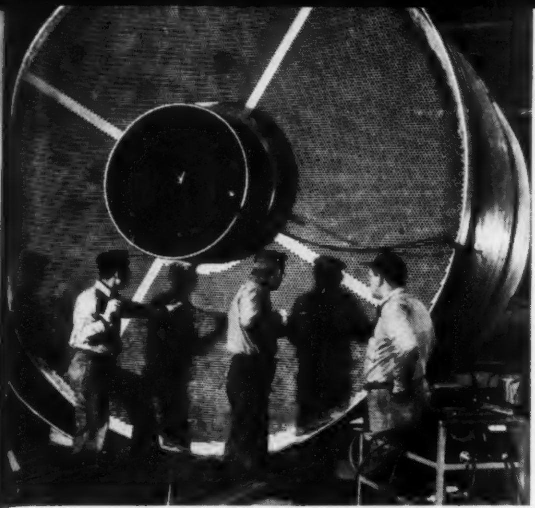
Iron Powders

Iron powder with CDF (controlled dimensional factor) is subject of illustrated bulletin 763. Advantages and characteristics of each type of powder and curves for their various properties are included, along with specifications and design pointers. 16 pages. Republic Steel Corp.

Circle 551 on page 19

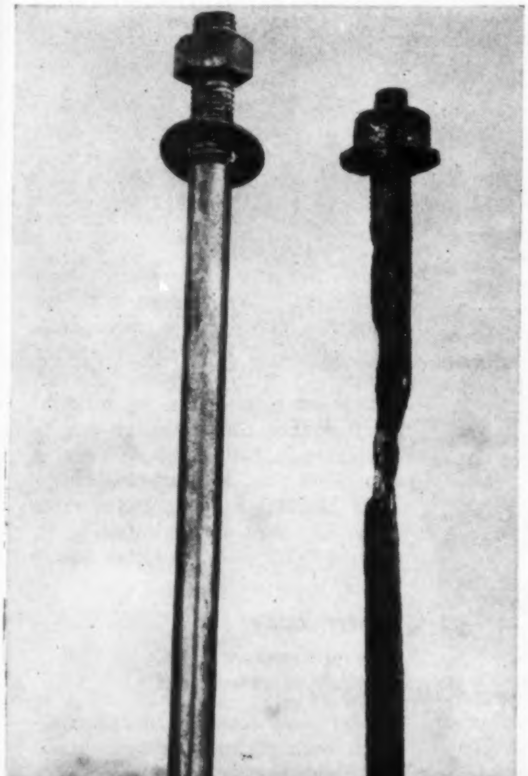
Casting Buyers' Guide

Lists of sources for gray iron castings in every industrial area are contained in Buyers' Guide and Directory. Data for each foundry includes type and size of castings produced, average production and executive personnel. Request from Gray Iron Founders' Society, Inc., National City-East Sixth Bldg., Cleveland 14, O.



FOR HIGH TEMPERATURE STRENGTH. This looks like a sieve, but actually it is a Stainless Steel plate punched with 25,400 holes, and it makes up the end plate of a chemical plant heat exchanger. After the tubes were inserted the exchanger was placed in high-temperature, intensely corrosive 24-hour service. It was made by the Nooter Corporation, St. Louis.

FOR CORROSION RESISTANCE. Rare Earths, Inc., produces such valuables as cerium, lanthanum and praseodymium by means of an elaborate chemical separation process. In the filter press, corrosion destroyed carbon steel plate rods in six months. Stainless Steel rods were installed over six *years* ago, and are still in fine condition.



NOTHING *can equal* *Stainless Steel*

for its combination of desirable properties

No other design material can match Stainless Steel in its combination of desirable properties: corrosion resistance, strength and hardness, beauty, cleanability and easy fabrication. When seeking a source of supply, remember that United States Steel offers you the widest range of types, finishes and sizes.

FOR TAKING A BEATING. These are 8th grade students from Dormont, Pa., public schools in a domestic science class. The sink tops were made by Pride Mfg. Co., Pittsburgh, from USS Stainless Steel. Says Pride, "These Stainless sink tops are ideal for school use. We've seen some 20-year-old sinks that still look as good as new."

UNITED STATES STEEL CORPORATION, PITTSBURGH · AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO · NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS
PIPE · TUBES · WIRE · SPECIAL SECTIONS

USS

UNITED STATES STEEL

Circle 444 on page 19

New Parts

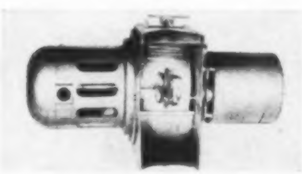
and Materials

Use Yellow Card, page 19, to obtain more information

Centrifugal Switch

withstands
1 million cycles

Syncro-Snap centrifugal switch operates on frictionless, snap-action principle that eliminates all wear associated with fly-ball spring-pivot governers. Typical application is installation in blower for gas furnace where switch stops gas flow in case of blower failure. In this case, switch is mounted on blower shaft and operates in conjunction with mercury switch. Accuracy is ±3 per cent of rota-



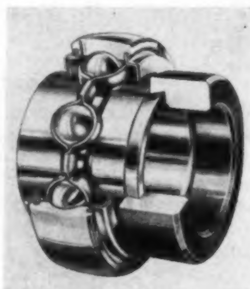
tional speed. Switch provides operating life in excess of 1 million cycles. **Torq Engineered Products Co.,** Interstate St., Bedford, Ohio.

Circle 552 on page 19

Ball Bearing

wide inner ring unit
has effective seal

Self-aligning, sealed, wide inner ring ball bearing seals out contaminants at slow to moderate speeds and retains supply of grease. Seal consists of two dished steel plates surrounding a synthetic rubber impregnated fabric sealing washer. Both plates are fixed in outer ring; inner plate provides backing for seal washer and baffle for grease retention. Outer plate permits seal to flare out in wiper fashion, insuring tight contact with inner ring. Bear-



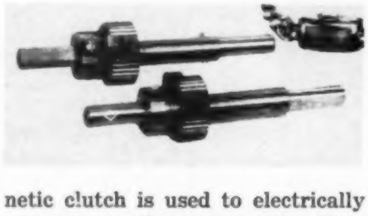
ing is available either relubricatable or nonrelubricatable in pillow block or two types of flange mountings. Size range is ½ to 2 15/16 in. bore, 1.575 to 5.118 in. OD, and 1 15/16 to 3⅝ in. overall width. **Fafnir Bearing Co.,** 37 Booth St., New Britain, Conn.

Circle 553 on page 19

Clutches

miniature units are
available in three types

Clutches are available in three types and are designed to disengage a particular subassembly from an entire system, either to render that portion inoperative when it is no longer required or to protect it from overload. Friction clutch provides clutch action at predetermined torque and can be set to stop at any torque from 2 to 20 in.-oz. Single drive mag-



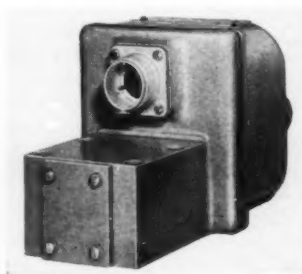
netic clutch is used to electrically connect or disconnect linkage at predetermined torque or previously set stages in operational sequence. Reversing magnetic clutch is used either as a reversing clutch or as a two-speed drive. Maximum power requirement of both magnetic units is 30 v, 27 amp; output torque is 40 in.-oz. **Servo Corp. of America,** 20-20 Jericho Turnpike, New Hyde Park, N. Y.

Circle 554 on page 19

Servo Valve

gives variable
flow control

Electro - hydraulic servo valve allows hydraulic control of variable delivery pumps, hydraulic motors, cylinders and similar



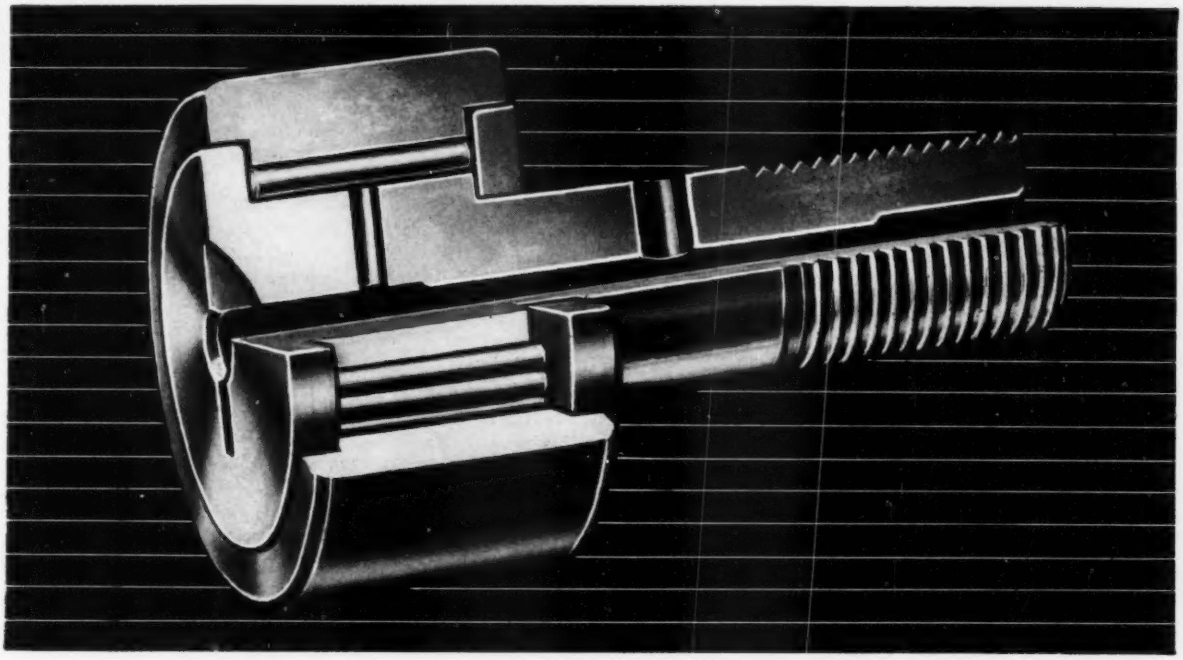
equipment. When used with an amplifier, three-way valve controls flow of oil to hydraulic linear or rotary - motion drives. Single-stage valve is driven by a high-performance torque motor and is available in ratings up to 10 gpm and 3000 psi. **Minneapolis-Honeywell Regulator Co.,** 2753 Fourth Ave. So., Minneapolis, Minn.

Circle 555 on page 19

Meter Relay

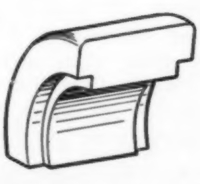
supersensitive unit
controls up to 1 watt

Meter relay features simplified design with platinum alloy contacts and high contact force which mini-



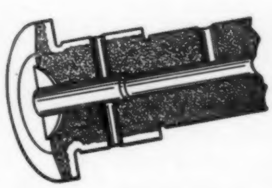
TORRINGTON CAM FOLLOWERS

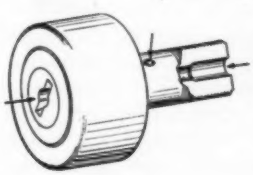
Give Longer Service . . . Carry High Shock Loads



1. Heavy sectioned outer race of hardened and ground high carbon chrome steel assures uniform distribution of high rolling and shock loads while providing high capacity anti-friction performance.

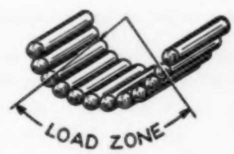
2. Integral stud for cantilever mounting is made of case hardened and ground low carbon nickel molybdenum steel. The tough core provides high strength to withstand high shock loads.

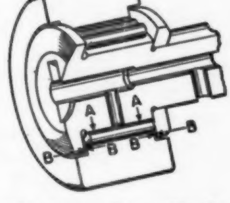




3. Easily relubricated at any one of three points—at either end or through cross hole in stud. Ends accommodate standard drive grease fittings, or may be sealed by the plugs provided.

4. Full complement of small diameter rollers—through-hardened, ground and lapped—for maximum radial load capacity.





5. Raceways precision ground for even load distribution (A) and uniform low end play (B) assure long bearing life.

Torrington Cam Followers are precision made throughout. They are available in sizes from ½" to 2¼" O.D. Special surface finishes such as chrome and cadmium plate or oxide black can be provided.

Our Engineering Department will be glad to work with you in adapting these dependable and efficient Cam Followers to your cam-controlled or track-type equipment. Torrington Cam Followers give better service because they're better made.

District Offices and Distributors in Principal Cities of United States and Canada

THE TORRINGTON COMPANY
Torrington, Conn. **South Bend 21, Ind.**

TORRINGTON BEARINGS

Needle • Spherical Roller • Tapered Roller • Cylindrical Roller • Ball • Needle Rollers

Circle 445 on page 19

mizes sticking and provides a high degree of reliability. Operating on power input of less than 50 millimicrowatts, relay will control up to 1 watt; power amplification is

20 million. Meter Relay is nonlocking type available in ac and dc models as microammeters, milliammeters, ammeters, millivoltmeters and voltmeters. Pyrometer type with bimetal compensation is also available. Four contact arrangements can be supplied. **Simpson Electric Co.,** 5200 W. Kinzie St., Chicago 44, Ill.

Circle 556 on page 19

Gear Motor

shaft-mounted unit has wide range of speeds

Shaft-mounted gear motor provides remote and automatic control for variable speed drives, valves, pumps, feeders and similar machines. Unit mounts on shafts from $\frac{1}{4}$ to $\frac{7}{8}$-in. diam and is light and compact. Both housing and cover are aluminum. Torque arm has resilient mounting to absorb any runout that may be present in shaft being controlled. When used on rising stem valves and similar

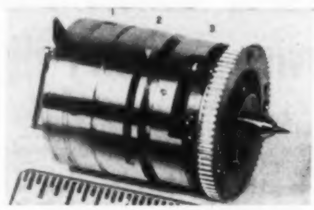
applications, torque arm is equipped with linear bushing to allow axial movement. Unit may be mounted either horizontally or vertically with shaft up or down. A wide range of output speeds and torque capacities is available. Single-phase unit has instantly reversible, permanent-split capacitor motor for high starting torque. Larger units are three-phase. Explosion proof and other enclosures are available. **Jordan Co. Inc.,** 3235 W. Hampton Ave., Milwaukee 9, Wis.

Circle 557 on page 19

Timing Mechanism

miniature unit provides time intervals to 168 hr.

Timer is built on a modular principle which permits extremely wide range of timing intervals and mechanical or electrical control functions. Unit is composed of three cylindrical cartridge units, each $1\frac{1}{4}$ in. diam. One module houses a mainspring to provide mechanical driving power for operating entire unit. Second module houses time measuring mechanism, and third module houses the control unit which contains a cam



driven by the power unit at a rate controlled by the timing mechanism. Unit can open or close an electrical circuit at desired intervals or provide a mechanical impulse. Time interval range is from a few seconds to 168 hours with accuracy of ± 1 per cent from -65 to 165 F. Unit will withstand accelerations of 3000 g for 10 milliseconds and has only slight reduction in accuracy when rotated upon its own axis at high speeds. **Hamilton Watch Co.,** Allied Products Div., Lancaster, Pa.

Circle 558 on page 19

Rubber Belting

has cord interliner to prevent stretching

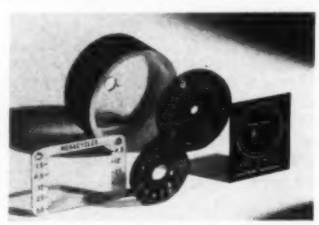
Seamless rubber belt for drive and feed-belt applications is nonstretching. Straight-line cord interliner, vulcanized between two layers of tough synthetic rubber, maintains unchanging length and eliminates possibility of slippage in applications where a positive drive must be held constantly. Belt has unusual flexibility, allowing use for such duties as drive belts on dictating machines, tape recorders, industrial pumps and compressors, or as feed belts on packaging machines, duplicating machines, and postage meters. Belts can be made in many lengths, widths, and thicknesses in almost any type of rubber including nitrile, styrene, neoprene and natural rubber or in combination. Rubber compounds have high surface friction for excellent power transmission and are resistant to oils, solvents, ozone cracking, and changes in humidity. **Armstrong Cork Co.,** Lancaster, Pa.

Circle 559 on page 19

Instrument Dials

produced with exceptional accuracy

Precision instrument dials have accuracy to 2 min of arc and graduations concentric to locating holes within 0.0005-in. TIR. A master is engraved on optical flat glass and dials are reproduced photographically, enabling reproduced dials to have sharp graduations as fine as 0.002-in. Process is suited for both short and long production runs. Dials are produced on met-



als and plastics such as aluminum, brass, steel, lamicoid and plexiglas. Plastic parts may be opaque, transparent, or translucent for back and edge-lighting effects. **Ackerman Engravers,** 458 Broadway, New York 13, N. Y.

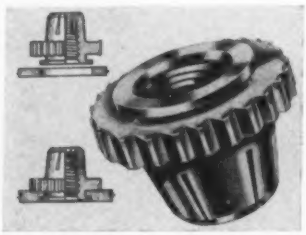
Circle 560 on page 19

Press Nut

provides flush mounting in pre-pierced hole

Sheet metal nut has thread-size range from No. 2 through No. 10. Nut fastens securely in sheet metal, offering flush mounting with

sheet thickness as low as 0.035-in. Design configuration locks nut in sheet both radially and axially. Nut is 303 stainless steel or Ledloy



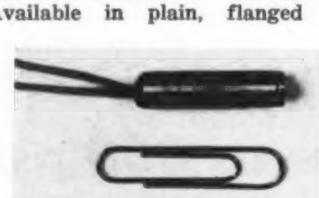
steel and meets AN-N-5 and AN-N-10 specifications. Installation is quick and simple, requiring only a hole in the sheet into which the nut is pressed. **Rosan Inc.,** 2901 W. Coast Hwy., Newport Beach, Calif.

Circle 561 on page 19

Miniature Thermostat

operates repeatedly on $\frac{1}{8}$-F differential

Subminiature thermostatic switch is only $\frac{1}{4}$-in. OD by 1 in. long. Uses are for precision temperature control in cathode tubes and other special and general applications. Available in plain, flanged or



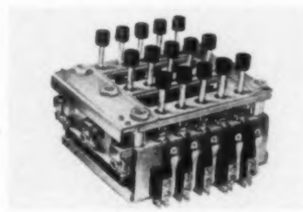
screwed head mounting, switch has either two-wire or grounded type construction. Rated load is 1 amp, 110 v ac. Operating ranges are 50 to 175 F, 150 to 275 F, or 250 to 275 F. Unit operates repeatedly on differential of $\frac{1}{8}$-F between make and break setting. **Scaico Controls Inc.,** Palmyra, N. J.

Circle 562 on page 19

Interlocking Switch

has up to 36 pushbutton switches

Interlocking pushbutton switch, mounted in parallel row assemblies to provide a maximum number of interlocked stations, is available in two types. Series 5900, illustrated, is available with up to 36 interlocking stations; Series 5700 has a maximum of 24 stations. Each station may be equipped with various contact combinations rated 3 or 5 amp, 110 v ac noninductive. In operation, each button depressed releases any previously operated station and locks itself in the



operated position. Features include a lock-out to prevent operation of more than one station at a time, solenoid release, and nonlocking stations. **Donald P. Mossman Inc.,** Brewster, N. Y.

Circle 563 on page 19

Plastic Adhesive

for automatic sealing of films

Hot-melt adhesive in coil form is called Thermogrip. Thermoplastic adhesive is designed for application with a feeding and melting device that can be attached to packaging or similar machinery for high-speed bonding of polyethylene films, foils, glassine, and other types of boards and papers. Adhesive eliminates clean-up, premelting and offers time advantages over manual application. Instant bond permits immediate secondary operations and combining of operations without slippage. **United Shoe Machinery Corp.,** 140 Federal St., Boston 7, Mass.

Circle 564 on page 19

Solenoid Valve

has independent manual adjustments

Solenoid valve provides independent controls for manual opening, adjustment of flow, and variation in opening and closing speeds. Known as Type HV, valve may be mounted at any angle. Available in sizes from $\frac{1}{2}$-in. to 2 in., valve has maximum capacity of 300 psi. Four independent controls are grouped in a cluster for convenient adjustment. Closing and opening adjustments are independent and have no effect on each

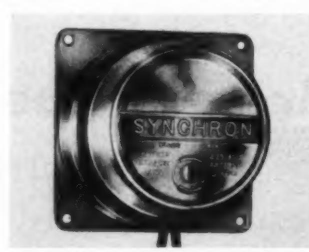
other. Manual opening stem allows operation in case of power failure. **J. D. Gould Co.,** 4707 Massachusetts Ave., Indianapolis 18, Ind.

Circle 565 on page 19

Timing Motor

has speed range of 0.8 to 2 rph

Small timing motor has speed range of 1 rpm to 1 rph without extra gearing. Motor is rated at 20 oz-in. at 1 rph and is for use in switches, timers and control applications. Unit has lifetime lu-



brication, is completely enclosed, and is available with optional one-way or two-way clutch. Speeds of motor are 0.8 to 120 rph at 60 cycle, 0.8 to 100 rph at 50 cycle, and 1 to 2 rph at 25 cycle. **Hansen Mfg.,** Princeton, Ind.

Circle 566 on page 19

Rubber Compound

has nonsticking characteristics

Rubber compound has outstanding nonsticking properties, making it ideal for valve seat and similar applications. Known as Compound No. 1318, material has excellent metal-bonding properties, yet gives quick break-away without lubrica-

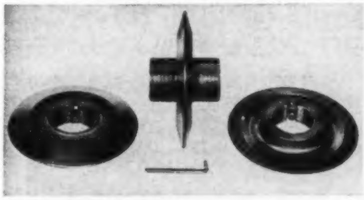
tion. Recommended temperature range of applications is −40 to 300 F. **Goshen Rubber Co. Inc.**, Box 517, Goshen, Ind.

Circle 567 on page 19

Adjustable Sheave

has increased power capacity

One and two-groove sheaves, for quick, easy speed adjustment for A and B section V-belt drives, are designed for low-power applications and provide increased maximum design power. Sheave, which is same size as standard, two-groove, B-section adjustable-pitch sheave, handles approximately three times more power. Keys



transmit all torque from shaft to hub and hub to disks. Set screw and key give positive lock between movable disks and stationary hub. Sheave illustrated is a two-groove unit. Outer flanges may be adjusted to proper distance from flange on hub to give belt pitch diameter desired. Sheaves for A section belts have 1 in. of PD adjustment; B section belt sheaves have 1.2 in. Horsepower range at 1750 rpm is 1.39 to 6.50 per belt. **Allis-Chalmers Mfg. Co.**, 1126 S. 70th St., Milwaukee 1, Wis.

Circle 568 on page 19

Insulating Varnish

has high heat resistance

New Class B insulating varnish is a polyester type material known as Isonel. Varnish has heat resistance similar to Class B wire enamels and handling and curing characteristics adapted to cycles and temperatures currently used by electrical manufacturers. Aging tests show that material has two to eight times life of Class A varnishes when aged at 200 C and subjected periodically to a 2000 v

Circle 447 on page 19

New Parts

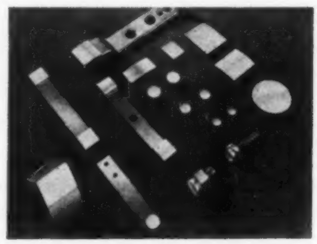
dielectric test. Varnish is completely heat reactive; at 180 C it cures to a tough, solid mass. Recommended thinner is mineral spirits; tank stability is excellent; and curing temperature is 375 to 400 F. **Schenectady Varnish Co. Inc.**, Schenectady, N. Y.

Circle 569 on page 19

Electrical Contacts

have high current-carrying capacity

Electrical contacts, containing silver and cadmium oxide, withstand larger currents than silver or silver-alloy contacts without welding or sticking. Gibsiloy compositions provide long life, high current-carrying capacities and increased electrical ratings. Contacts have excellent arc-quenching



traits, low contact resistance, high conductivity and low material loss. Applications include motor-starting and limit switches, light and medium-duty contactors and relays, aircraft relays and industrial controls. Properties of four contact materials available offer conductivity range of 75 to 80 per cent IACS, Rockwell F hardness of 40 to 60, and density of 9.4 to 9.6. Contacts are available in disks, rectangles, irregular shapes, and rivets. **Gibson Electric Co.**, 8355 Frankstown Ave., Pittsburgh 21, Pa.

Circle 570 on page 19

Circuit Breakers

standardized units in two case sizes

Molded case enclosed circuit breakers and enclosures in Type E, F and J frames provide plug-in ratings from 15 to 225 amp in only two NEMA 1A general-purpose enclosures. Two additional enclosures are designed for conventional

bolted-in Type K, KL and L frame breakers. Circuit breakers have stabs attached and visible disconnect safety. Down time is minimized due to ability to carry tem-

porary light overloads. Quick-make and quick-break mechanism with deionization-type arc quenching provides long service life. Units have accurate, tamperproof calibration, positive motor protection and low power loss. **Federal Pacific Electric Co.**, 40 Paris St., Newark, N. J.

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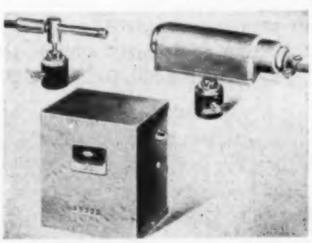
Photoelectric Control

miniature units are 3 in. long

Photoelectric control has miniaturized components and features simple design, ease of installation, accuracy and dependability. Photo cell and light source units are each about 3 in. long, permitting installation in tight places and are



swivel mounted for ease of installation and alignment. Cell unit uses a cadmium sulfide cell for long life and high sensitivity. Control circuits, signal lights and counter are housed in steel case which can be installed in a remote location. Unit will count up to 600 operations per minute. **Standard Instrument Corp.**, Robot-Eye Photo Control Div., 657 Broadway, N. Y. 12, N. Y.

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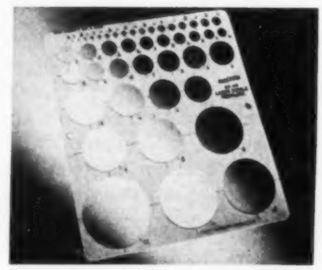
ENGINEERING DEPARTMENT EQUIPMENT

Circle Template

for circles to $2\frac{1}{4}$ in. diam

Template has 45 circles with diameters from 1/16 to $2\frac{1}{4}$ in. with pencil allowance. Template is 0.030



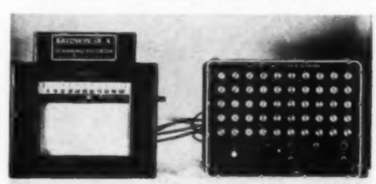
matte-finish plastic with ink filled markings. Size is $7\frac{1}{4}$ by $8\frac{1}{4}$ in. **Rapidesign Inc.**, Box 592, Glendale, Calif.

Circle 573 on page 19

Scanning Recorder

for strain gages gives concurrent data

Automatic 50-point scanning recorder for SR-4 strain gages can accommodate either two-arm or four-arm strain-gage bridges by positioning of selector switch. Four ranges cover 0-1000, 0-2000, 0-5000,



and 0-10,000 mu in. Individual stress-strain curves can be plotted automatically for each channel during test, providing immediate information on possible structure failure. Instrument has manual adjusting knobs for gages with resistances ranging from 60 to 500 ohms and gage factors between 1.77 and 2.25. **Baldwin-Lima-Hamilton Corp.**, Electronics and In-

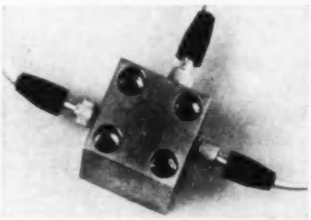
strumentation Div., 806 Massachussetts Ave., Cambridge 39, Mass.

Circle 574 on page 19

Accelerometer

subminiature unit measures three-axis accelerations

Subminiature high-temperature accelerometer measures three mutually perpendicular accelerations simultaneously. Designated Glennite Model AHT-30T, unit operates accurately in temperatures from —65 F to 350 F, has acceleration range up to 500 *g*. frequency response from 25 to 20,000 cps, and sensitivity of 0.8 mv per *g*. Unit weighs less than 1 oz and is less than 1 cu in. in volume. **Gulton Industries, Inc.,** 212 Durham Ave., Metuchen, N. J.



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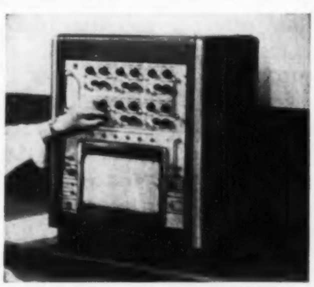
Amplifier Unit

has measurement range of 0.050 to 400 v

Multi-channel dc amplifier unit consists of six interchangeable plug-in dc amplifier sections, a power supply and a six-channel oscillograph. Amplifier unit has measurement range from 0.050 to 400 v, excellent zero line stability and frequency response of 100 cycles dc. **Brush Electronics Co.,** 3405 Perkins Ave., Cleveland 14, Ohio.



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THE ENGINEER'S

Library

Recent Books

Pulse and Digital Circuits. *By Jacob Millman, professor of electrical engineering, Columbia University, and Herbert Taub, associate professor of electrical engineering, City College of New York; 687 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 36; available from* MACHINE DESIGN, *$12.50 postpaid.*

This text for senior and graduate college courses provides a description and an analysis of the circuits and techniques common to many fields of electrical engineering. The 18 chapters include discussions of amplifier circuits, wave-forming, linear-pulse amplifiers, multivibrators, time - base generators, oscillators, counting, digital-computer circuits, voltage comparators, and transistors.

Applied Electrical Measurements. *By Isaac F. Kinnard, manager of engineering, Instrument Department, General Electric Co., West Lynn, Mass; 600 pages, 6 by 9 in., clothbound; published by John Wiley & Sons Inc., 440 Fourth Ave., New York 16; available from* MACHINE DESIGN, *$15.00 postpaid.*

This volume is divided into two parts. Part 1 covers the measurement of electrical quantities including current, potential difference, resistance, power, energy and magnetism. Part 2 discusses the measurement of nonelectrical quantities such as light, heat, sound, liquids, gases and time. Also included are chapters on the history, theory and functional analysis of measurement and a review of the state of applications in selected fields.

A Human Engineering Bibliography. *By Ivan N. McCollom, professor of psychology, San Diego State College, and Alphonse Chapanis, professor of psychology and industrial engineering, The Johns Hopkins University; 128 pages, 8½ by 11 in., paperbound;*

published by and available from San Diego State College Foundation, San Diego 15, Calif.; $4.00 per copy.

Compiled for design engineers, this bibliography lists published material in the entire field. Nearly 5700 published works are listed in 26 different categories.

Association Publications

Symposium on Impact Testing. 170 *pages, 6 by 9 in., paperbound; published by and available from American Society for Testing Materials,* 1916 *Race St., Philadelphia 3, Pa.;* $2.65 *per copy to members,* $3.50 *to nonmembers.*

This book gives 14 papers presented at the 58th annual meeting of ASTM. The papers cover all phases of impact testing, including notched bar testing, Charpy impact test, impact tube test, testing methods, and results of impact testing on various materials.

Machine Tool Electrical Standards. 20 *pages,* 8 *by* 11 *in., paperbound, side-stapled; published by and available from National Machine Tool Builders Association,* 2071 *E.* 102*nd St., Cleveland* 6; *free of charge.*

These revised standards, adopted March 1, 1956, include definitions of terms, wiring diagrams, conductors, gaskets, grounding, identification, switch interlocking, equipment mounting, circuit protection, switches and circuit breakers.

Government Publications

Hydraulic Research in the United States. 8 *by* 10 *in.,* 216 *pages, paperbound; published by and available from U. S. Department of Commerce, Washington D. C., and available from Department of Commerce Field Offices;* $1.50 *per copy.*

This bulletin covers projects conducted at universities, hydraulic and hydrologic laboratories in the United States and Canada, and government agencies. All active projects are included. Qualified inquirers may secure information concerning any project from National Bureau of Standards or from the individual laboratories as listed in the bulletin.

New Machines

Domestic

Radio - Phonograph: Concerto Model TP265C high-fidelity radio-phonograph combination has compensated volume control, variable treble and bass control. Four-speed intermix record changer is equipped with automatic shutoff and automatic muting switches. Pickup has dual sapphire styli. The AM radio tuner has high sensitivity for distance reception. Six-watt amplifier uses four tubes including rectifiers and is equipped with push-pull output stage and crossover filter network. Built-in AM antenna and one 5 in. and two 6 x 9 in. front-mounted oval speakers with sound diffusers are incorporated. *Magnavox Co., Ft. Wayne, Ind.*

Kitchen Appliances: Twelve refrigerator models have a redesigned door which is set into the refrigerator cabinet. Some models are equipped with ice ejector which provides cubes in a storage and serving bin at the pull of a lever. Capacities range from 12.4 to 8 cu ft. Ten porcelain-finished electric ranges are available in 30 and 40-in. sizes. Line includes models with two ovens, large-capacity single ovens, and oven that broils and bakes simultaneously. One model has a fast, sealed broiler unit and filter that removes oven cooking smoke. The filter operates automatically whenever the oven is in operation. *General Motors Corp., Frigidaire Div., Dayton, O.*

Tape Recorder: SRT-2 high-fidelity magnetic tape recorder incorporates transistors, printed circuitry, and electrodynamic operation. The recorder covers the audible range from 30 to 15,000 cycles, utilizes all types of standard magnetic tapes in 5 and 7-in. reels, and can be installed vertically or horizontally. The dual-speed unit operates at 7½ and 3¾ in. per second, and has forward and rewind speed of 1200 ft of tape

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in 45 seconds. Chassis is 10½ in. high, 19 in. wide, 8½ in. deep; weight is 35 lb. *Radio Corp. of America, Theater & Sound Products Dept., Camden, N. J.*

Materials Handling

Lift Truck: Dust - protected, gasoline-powered industrial lift truck permits materials handling in locations containing atmospheric abrasives. Tandem air-cleaning system filters air going into the carburetor. Air passes first through a dry - type precleaner mounted on the top of the truck hood, then through a heavy-duty oil bath cleaner. A heavy-duty air filter is provided on the crankcase breather pipe. Truck bottom is equipped with a deflector plate which keeps foreign particles on the floor from being drawn up into the engine compartment. The plate can be removed easily for servicing the truck. Generator and voltage regulator are totally enclosed. *Yale & Towne Mfg. Co., Yale Materials Handling Div., Philadelphia.*

Transfer Table: In-line transfer table without fixtures transfers piece parts from station to station for automatic or manual operations. It can be adapted to multiple, consecutive operations and handles 6400 pieces per hr. Designed for parts having a flat surface on which to slide along a track, the table cam-locks parts at each station within 0.005-in. tolerance without auxiliary locating devices. When tolerance is less than 0.005-in., a shot pin or locating lug can be utilized. Base support contains intermittent drive unit. It is located at either end or in the middle of the table. Index distance can be varied from 3 to 9 in. and index time from 0.25 to 0.7-second. Fast indexing is accomplished with total cycle time from 0.56-second. Dwell time is adjustable. The tables are available in lengths from 5 to 12 ft. *Dixon Automatic Tool Inc., Rockford, Ill.*

Metalworking

Swing Lathes: WM56P 11 and 13-in. swing lathes have heavy-

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duty, adjustable-speed drives and spindle speeds from 40 to 300 rpm in back gear, 200 to 1800 rpm in direct drive. Speed changes are made by raising or lowering a T-handle speed - selector lever. Tachometer dial built into the headstock shows actual spindle speeds. Stops can be set on the speed selector for automatic selection of two predetermined speeds. Heavy-duty drive unit is equipped with a 2-hp, 3-phase motor. Machine also has a 54-pitch gear box and friction disk clutch for engaging power longitudinal and power cross feeds. Flame hardened bedways, taper key drive spindle noses, bed turrets and air attachments are available. Variety of bed lengths have center distances of 26, 36 and 48 in. *Sheldon Machine Co. Inc., Chicago.*

Disk - Filing Machine: Jemco disk-filing machine removes ferrous and nonferrous metal, wood and plastics. It can be equipped with two disks simultaneously, ranging in size from 3⅛ to 12 in. For cutting nonferrous metals, disks are available in carbon steel. Disks of high-speed steel and carbide are provided for ferrous metals. All disks have ground teeth which can be resharpened. Work table provides for mounting fixtures or sliding tables for special operations. The unit is powered by a 1-hp motor which turns disks at five standard speeds from 175 to 410 rpm. Additional speeds can be achieved by changing pulleys. *Jersey Mfg. Co., Elizabeth, N. J.*

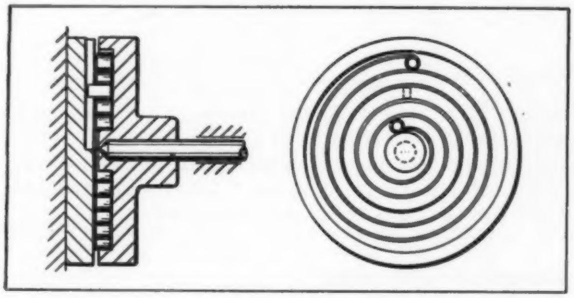
Cold-Heading Machine: Headmaster solid-die, double-stroke cold header heads rivet and screw blanks at rates of 300 to 450 per minute. Toggle-actuated gate produces two blows for each flywheel revolution. Friction-roll feed makes possible maximum control in feeding. All shafts are mounted in roller bearings to reduce friction. Other features include centralized lubrication and high-tensile gray-iron cast frame. Unit heads ⅛ x ¾ rivets, No. 6 x ¾ machine screws and No. 8 x ¾ sheet metal screws. *Waterbury Farrel Foundry & Machine Co., Waterbury, Conn.*

N O T E W O R T H Y

Patents

Rotational-Stop Mechanism

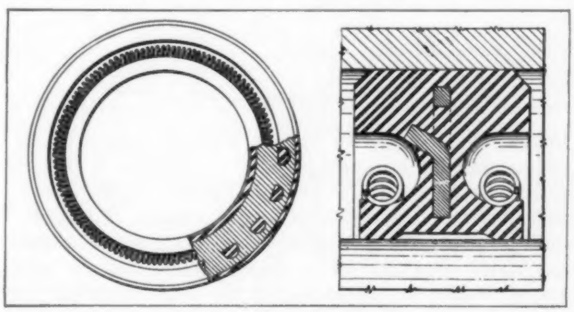
Positive stop action after a predetermined number of turns is provided by a rotational-stop mechanism employing a moving block and a fixed spiral spring



as principal components. Block tracks radially in the space between adjacent turns of the spring until it contacts stop pins at each end of the spiral. If desired, spring can be replaced by one with a different number of turns to vary allowable rotation of the controlled shaft. *Patent 2,746,573 assigned to Bendix Aviation Corp. by Donald F. Hastings.*

Mechanical Seal

Permanent set in the flexible members of a mechanical seal is minimized by an embedded metallic reinforcing washer. Positive positioning of the washer



is ensured by its multiple tang construction. Sealing action of the flexible annular member, which is either natural or synthetic rubber, is provided by conventional garter springs. *Patent 2,736,583 assigned to General Motors Corp. by John T. Marvin.*

Multiple-Disk Clutch

Smooth engagement and shock-free load pickup of a clutch or brake is provided by the spring action of tanged Belleville-spring disks interleaved with multiple friction disks. Tangs, spaced on the outer

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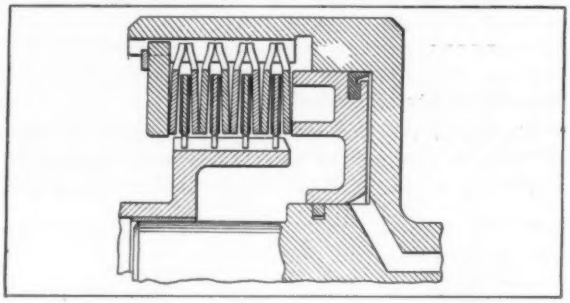
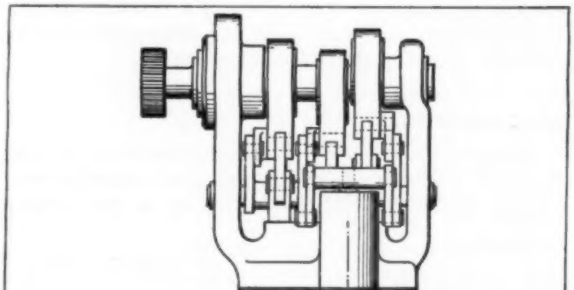
peripheries of the Belleville disks, come together first when engagement of the clutch is initiated by an annular piston. Continued engaging action, with resulting flexing of the spring disks, separates the



tangs, permitting full engagement of the sintered-metal friction surfaces with the spring disks. Positive disengagement is insured by the return spring action of the tangs. *Patent* 2,738,864 *assigned to Borg-Warner Corp. by Sylvan J. Becker.*

Variable-Stroke Pump

Stroke length is varied automatically in response to changes in discharge pressure in a variable-volume, constant-pressure, piston-type pump. Volume of fluid delivered to the output manifold depends upon



length of stroke. As output pressure tends to decrease, stroke is lengthened by a bell-crank mechanism positioned by a control piston. High output pressure similarly reduces piston stroke. Pump discharge pressure is therefore maintained at a substantially constant value despite variations in load. Pump shown is a three-cylinder unit intended for use in a sump or reservoir. *Patent* 2,754,806 *assigned to Bendix Aviation Corp. by Frederick D. Funston.*

Thermally controlled valve for accurately bleeding minute quantities of fluid into high-vacuum systems makes use of the difference in thermal expansion between the valve plug and a surrounding, electrically heated tube. Flow through valve can be controlled from a few molecules to a steady stream at output pressures as low as 10^{-9}-mm Hg. *Patent* 2,749,934 *assigned to E. I. du Pont de Nemours by Ralph G. Nester.*

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HALF A MILLION

'VARIATIONS ON A THEME'

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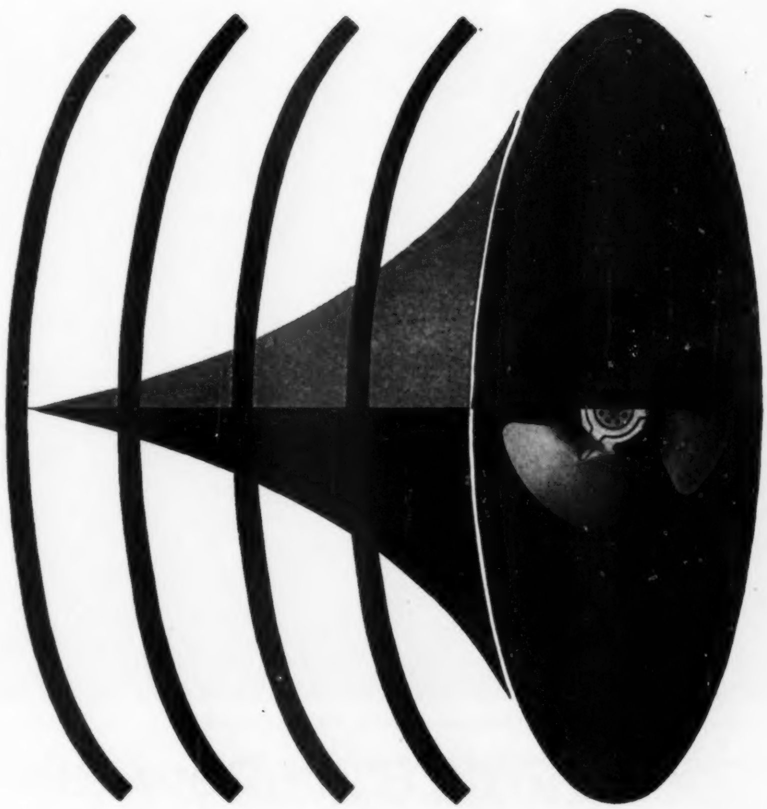

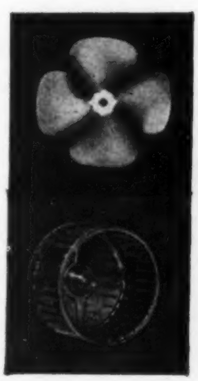

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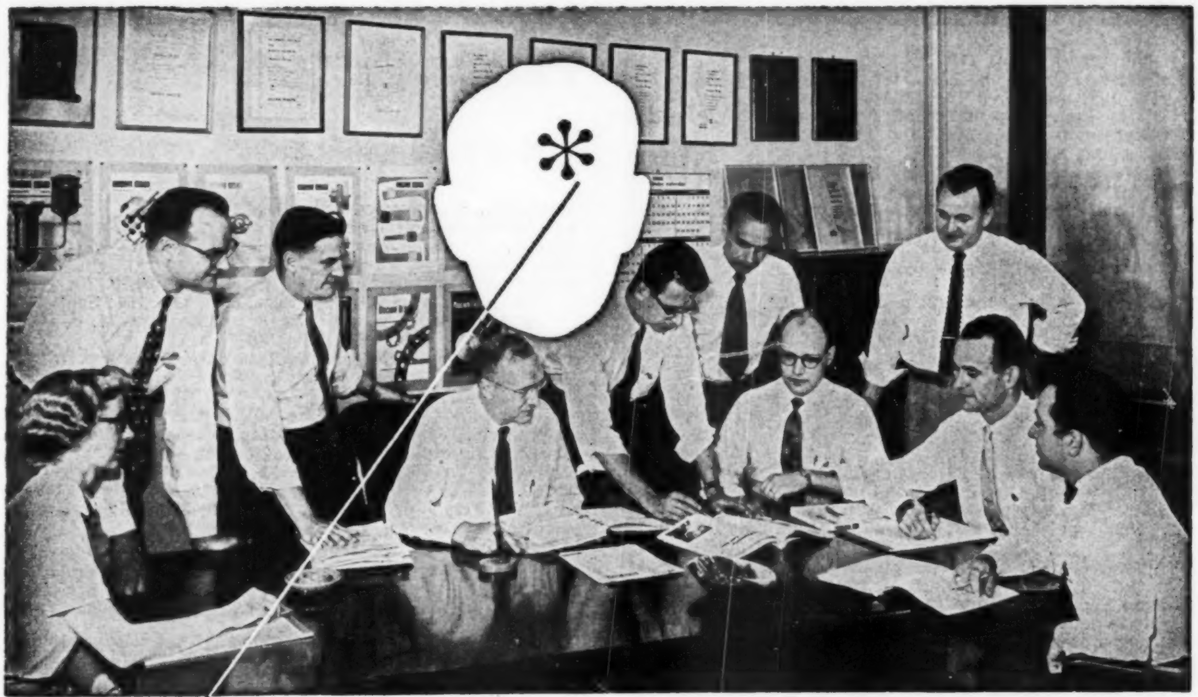

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D

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MAYLINE

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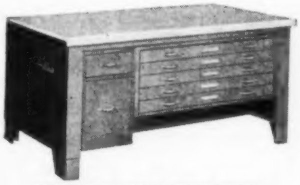

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FASTENERS by NATIONAL LOCK

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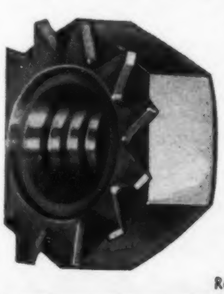

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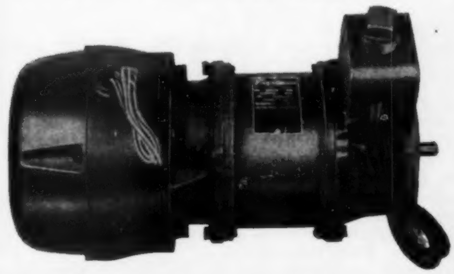
Where Special Requirements Dictate Motor Construction



This peculiarly shaped motor opens and closes pipe line valves without fail in all types of weather. It is a special weather-proof torque motor designed by **Peerless Electric** in cooperation with a valve manufacturer and is equipped with an electrically operated brake. The motor shown here measures approximately 10" in diameter and 31" in length but Peerless can produce it in many other sizes.

The outstanding product performance attained with this motor is a result of teamwork engineering — Peerless — OEM cooperation. Submit your next motor problem to Peerless. We'll work with you to design or select the one motor that operates your product best.

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ENGINEERS

AVAILABLE OR WANTED

WANTED: Instructor, Assistant Professor, Associate Professor, Professor openings—to teach thermodynamics, heat transfer, fluid mechanics, machine design, stress analysis, nuclear engineering, shop processes or combinations in fields mentioned. M. S. required, Ph. D. desirable. Rank and salary commensurate with qualifications. Opportunities for sponsored research and consulting. Write Professor C. T. Grace, Chairman, Mechanical Engineering, University of New Mexico, Albuquerque, New Mexico.

WANTED: Engineer, Research and Development. BS in Mechanical, Electrical or Electronic Engineering. Five-ten years in Development and Design of Mechanical or Electro-Mechanical devices. Experience in Design of Control Valves and Automatic Controls desirable. We desire an original thinker who can supply and develop new ideas for an expanding line of Control Valves and Automatic Control devices and follow through to the finished product. Forward looking, steady growth company with broad program of liberal employee benefits, pleasant working conditions. Thirty minutes from Mid-town New York. An excellent opportunity for the right man. Leslie Company, Grant Avenue, Lyndhurst, New Jersey.

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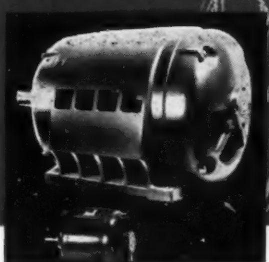
BPA NBP

Why not build the cart before the horses?



Just tell us here at Master what you want in power drives—and get the utmost in flexibility, compactness and performance. It probably won't be as complicated as the multi-shaft Gearmotor illustrated here, with 14 shafts turning at diverse speeds. But, regardless of what you need, Master can supply the right combination of horsepower, shaft speed and mounting features with whatever Master components are required—all combined in one compact efficient unit. Just ask for information.

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Motor Types... Squirrel cage, slip ring, synchronous, repulsion-start induction, capacitor, direct current.

Construction .. Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.

Speeds........ Single-speed, multi-speed, and variable speed.

Installation.... Horizontal or vertical, with or without flanges and other features.

Power Drive Features...... Electric brakes (2 types)—5 types of gear reduction up to 432 to 1 ratio. Mechanical and electronic variable speed units—fluid drives—every type of mounting.

THE MASTER ELECTRIC COMPANY, Dayton 1, Ohio

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